SIEMENS Programmable Logic Controllers

In English

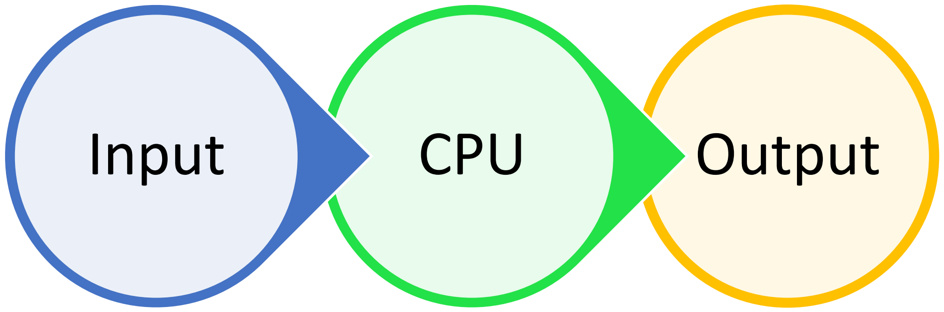
Instructor: Rana Muhammad Awais

SO WHAT IS PLC

Programmable Logic Controller (PLC):

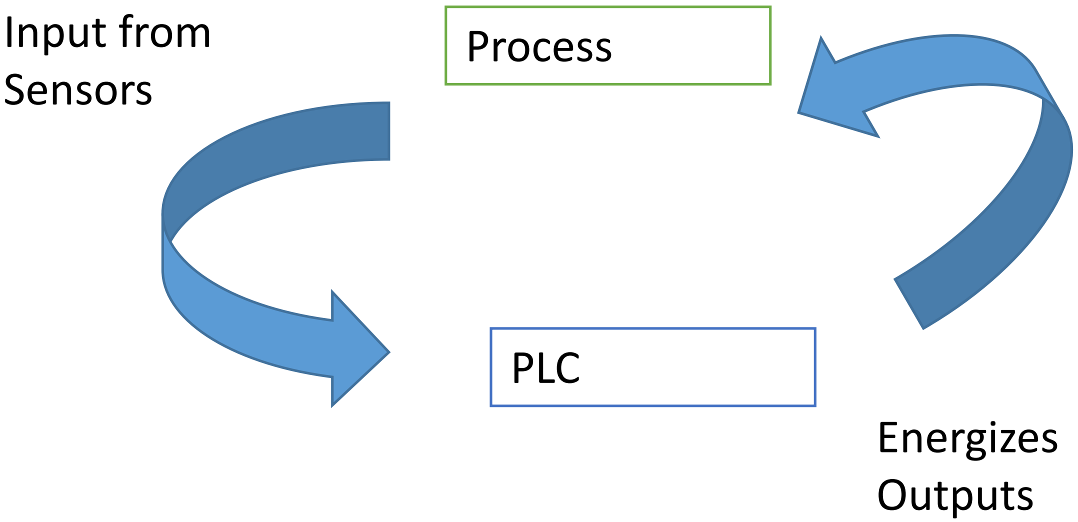
Programmable Logic Controller is an industrial-grade computer used for automation of machinery and processes in an industry by controlling inputs and outputs through the programmed logic. It takes signals from *sensors (inputs)* and *energizes actuators (outputs)* based on the *logic* programmed while working in *real time*.

(Follows Standard IEC 61131-2 for PLC)



Benefits:

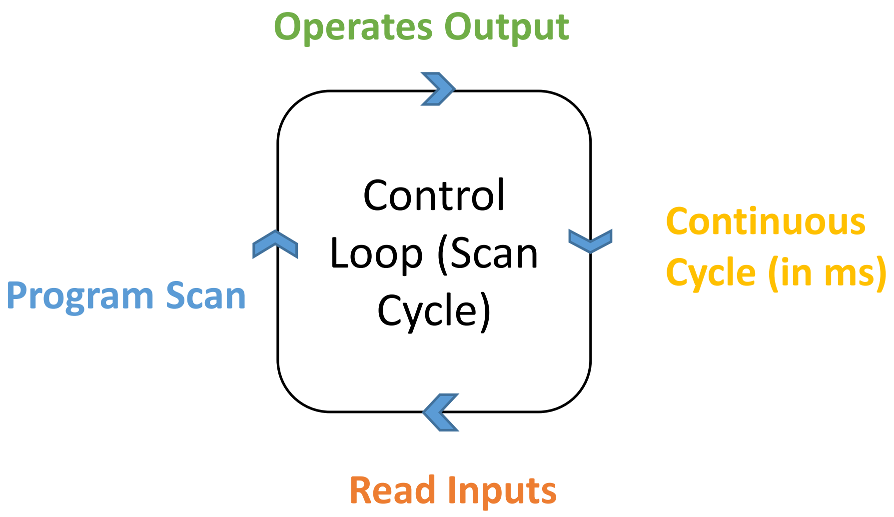
1. Higher reliability
2. More flexibility as changes can be made within program
3. Cost effective for controlling complex systems
4. Easier programming and troubleshooting
5. Faster response time
6. Immune to electrical noise
7. Resistance to Vibration



Programmable Logic Controller:

(PLC) is an industrial computer control system that automate processes by:

- Read Inputs
- Program Scan
- Energizes the Outputs
- Continuous Cycle



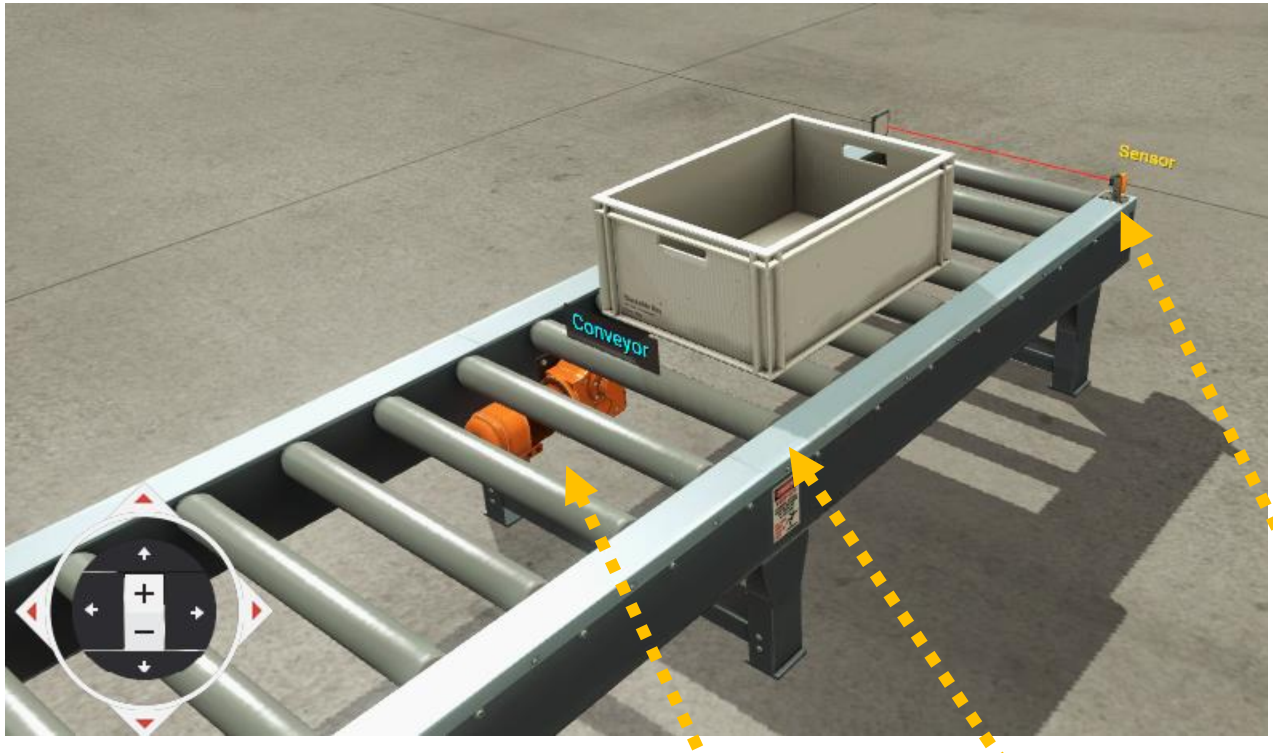
PLC can be divided into three parts:

- CPU
- Inputs/Outputs
- Programming Device

PLC OPERATION

Let's have a look at a simple process.

- Boxes being transported till it reaches the sensor
- Motor is running the conveyor
- When the boxes reach the sensor, the sensor sends a signal to relay or PLC
- Thus stopping the motor

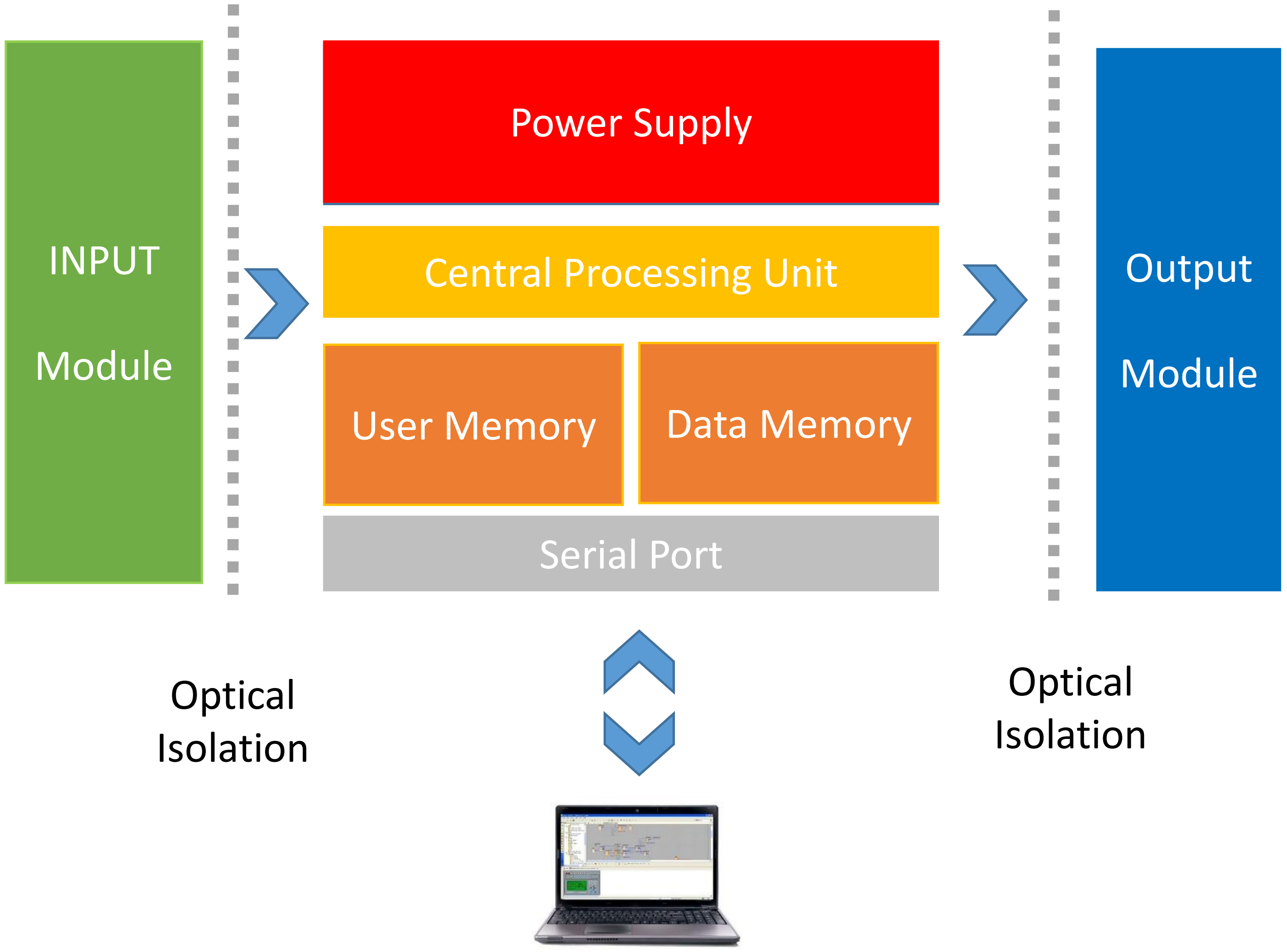


Sensor (Input)

Motor (Output)

Process (Boxes transported through a conveyor)

PLC OVERVIEW



Applications

PLCs are common choice for systems having discrete I/Os and fixed logic. Also for machine control and motion control. For higher Analog Control and Continuous (process) applications, Distributed Control System (DCS) Is preferred

PLCs have three major types of applications:

Single Task – single process being controlled by single plc (stand – alone)

Multi Task – multiple processes being controlled by single PLC having many I/Os

Control Management – Master PLC Controlling multiple PLCs for complex processes

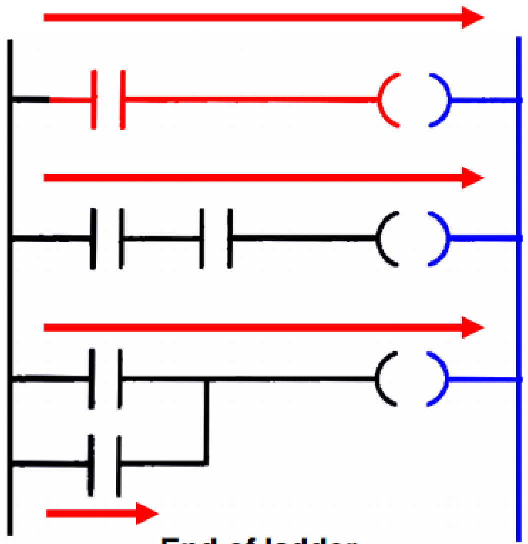
Programmable Logic Controller:

PLC can be programmed using standard programming languages IEC 61131-1 standard. :

Currently Five Languages are commonly used:

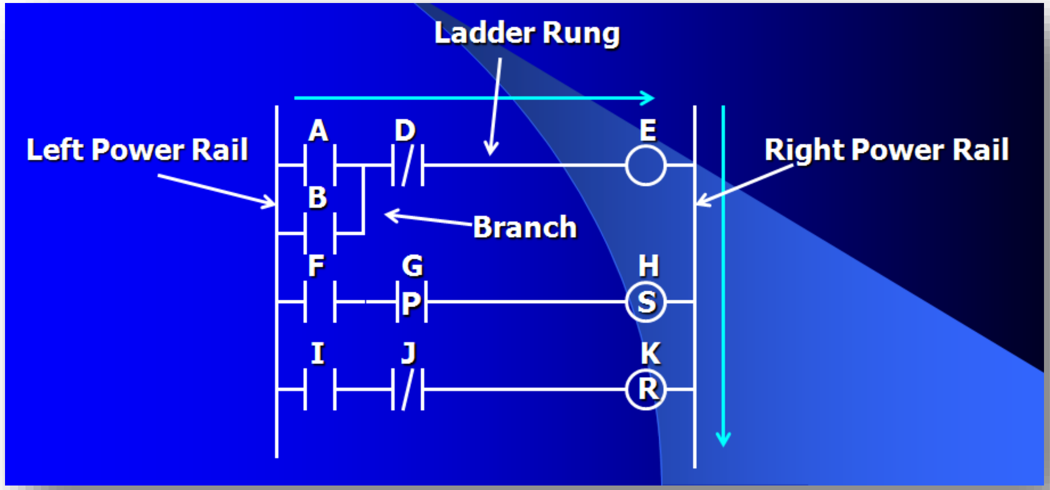
- Functional Block Diagram (FBD) –Graphical (For Process Flow)
- Ladder Logic (LD) – Graphical (For Electrical Flow)
- Structured Text (Similar to Pascal) – Textual (Textual, Calculative)
- Instruction List (Similar to Assembly) – Textual (Boolean)
- Sequential Function Chart (SFC) – *Graphical (Sequential Process)*

Scan Patterns



Horizontal Scanning Order

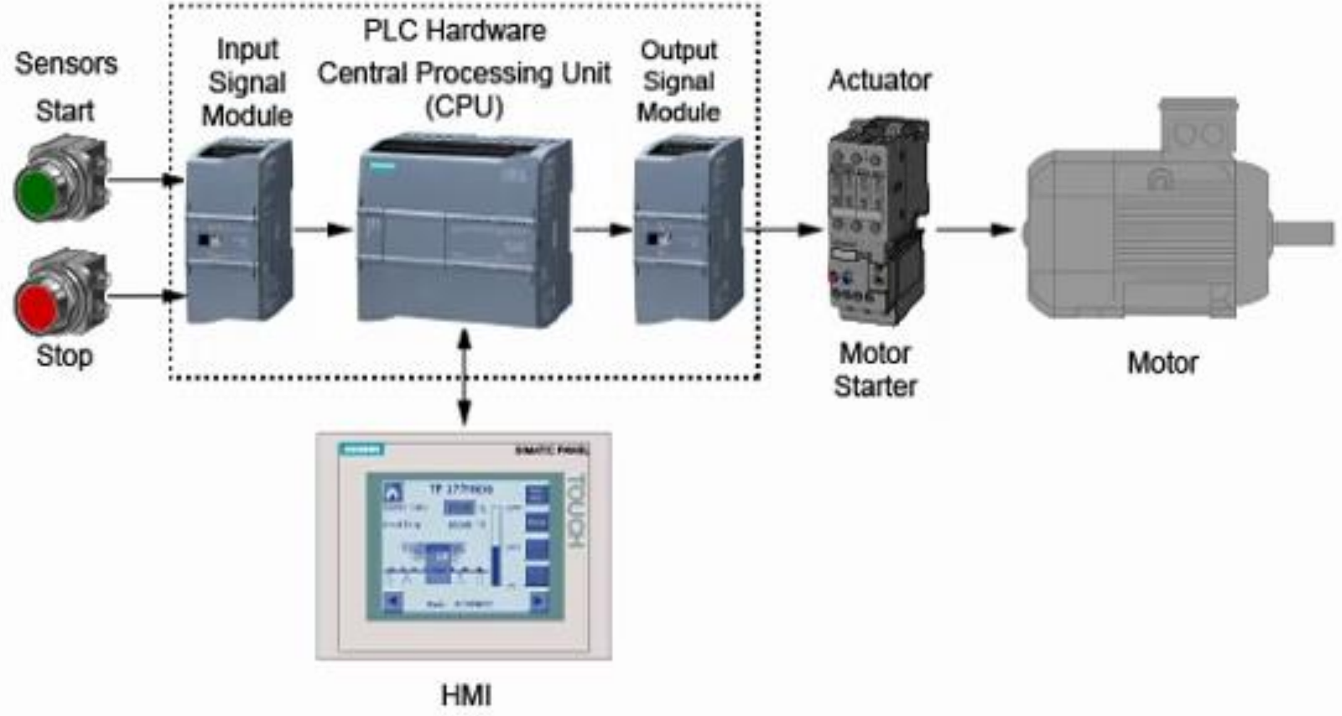
The processor examines input and output instructions from the first command, top left in the program, horizontally, rung by rung.



In addition to the program itself, the scan time is also dependent on the clock frequency of the processor!

PLC Hardware

PLC Hardware



A PLC is made up of both hardware and software. Hardware is the part of a system that you can see, and software is the collection of computer programs that control what the hardware does.

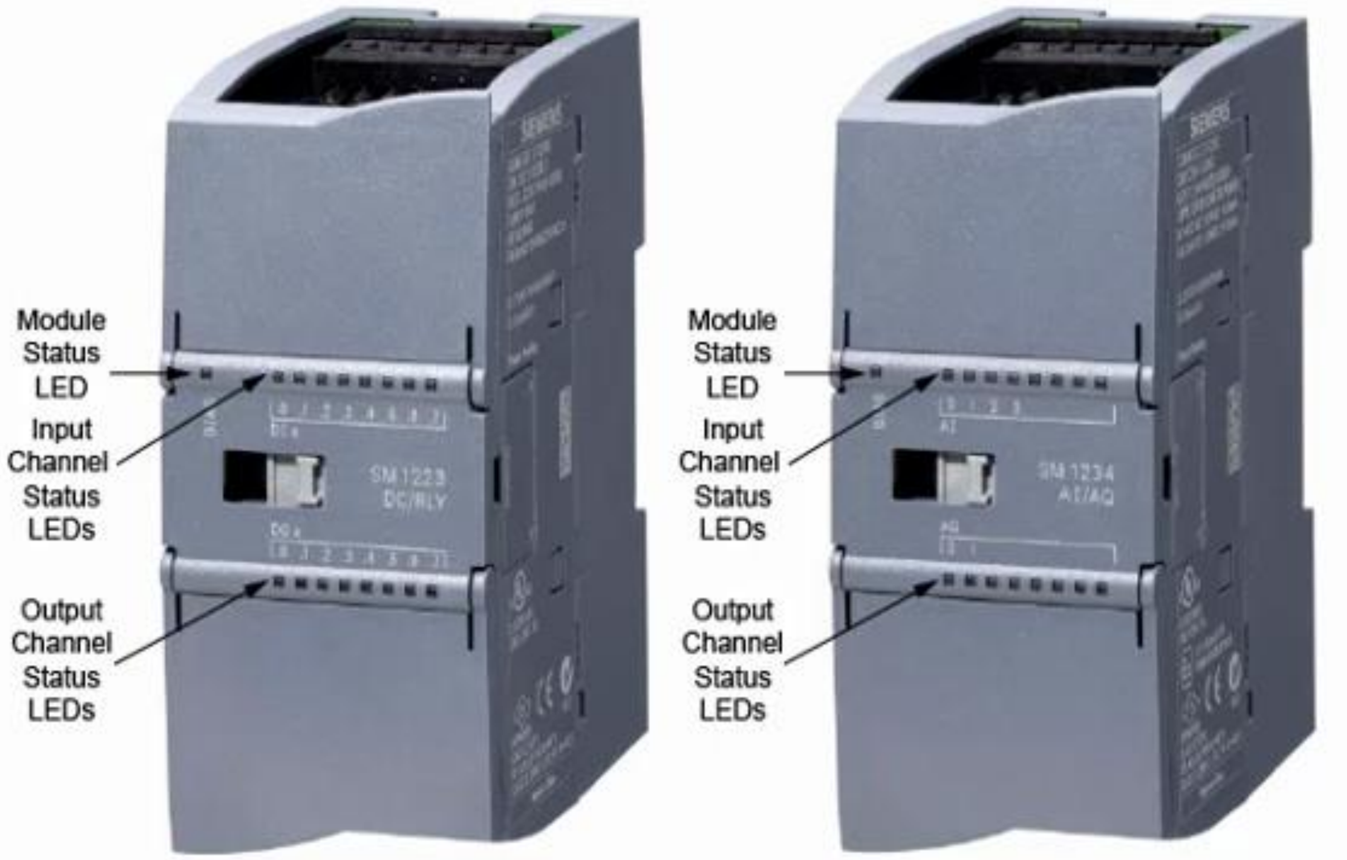
PLC hardware also connects to other hardware, such as input and output devices and human machine interfaces (HMIs).

Because PLC applications vary in complexity, there is considerable variation in the appearance of PLC hardware.

Additionally, because the needs of customers vary widely, Siemens SIMATIC PLCs are available as modular controllers, embedded controllers, or as PC-based controllers. Of these three categories, modular controllers are the most common and are the focus of this course.

Source: Siemens

Signal Modules



Combination Discrete Input/Output Signal Module

Combination Analog Input/Output Signal Module

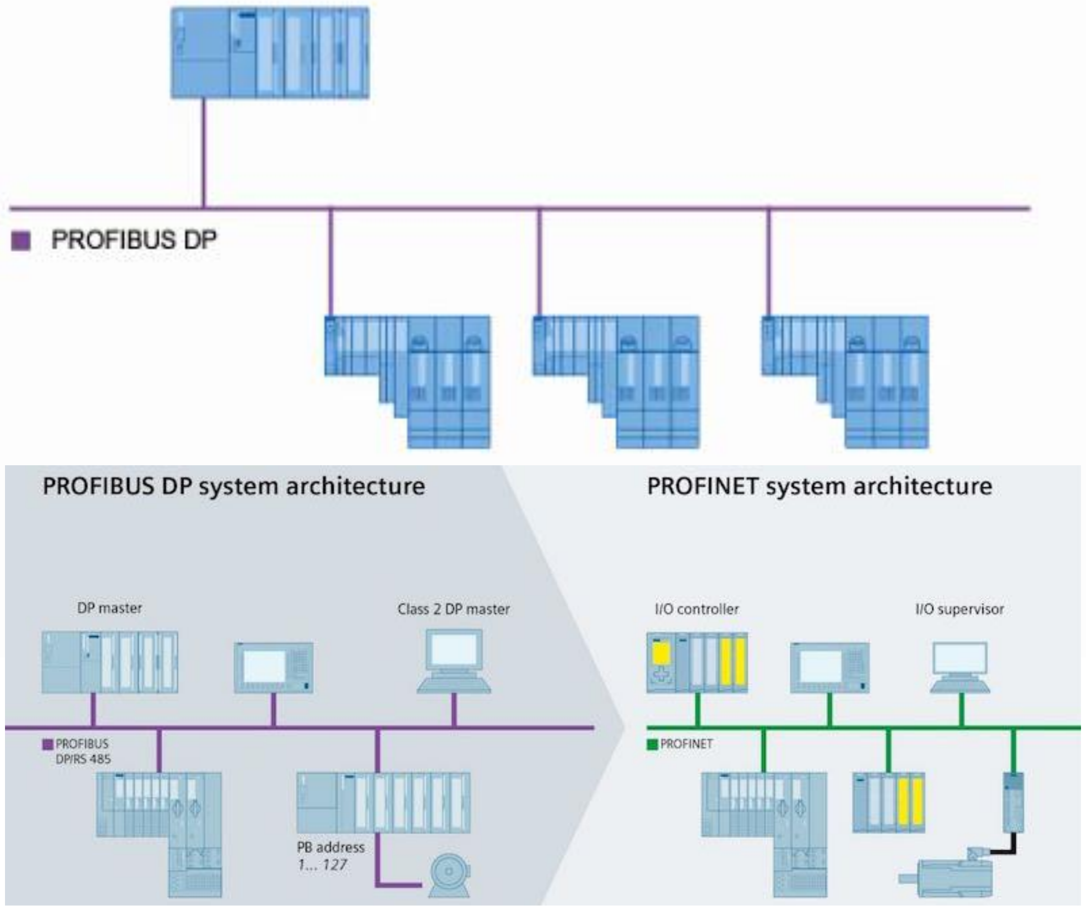
PLCs have a variety of signal module types. Each module has multiple I/O channels, and each I/O channel connects to one I/O device.

The number of I/O channels on a module varies with the module type. Some modules also have both input and output channels.

Signal modules of various types are interspersed as needed throughout a system. Each module is configured at installation, and this configuration includes the assignment of a module address. This address together with the module type also identifies the location of image table status bits for the connected inputs and outputs.

Source: Siemens

Communication Modules



Afield bus is an industrial network used for distributed control. One example of a fieldbus is PROFIBUS DP.

With the growth in information technology (IT), the need for control systems to communicate with IT systems increased.

IT systems often communicate via Ethernet local area networks (LANs); however, the original form of Ethernet was not adequate for factory communication, so Industrial Ethernet was developed. PROFINET is the leading Industrial Ethernet standard.

A PLC CPU often has one or more ports for a specific type of network communications.

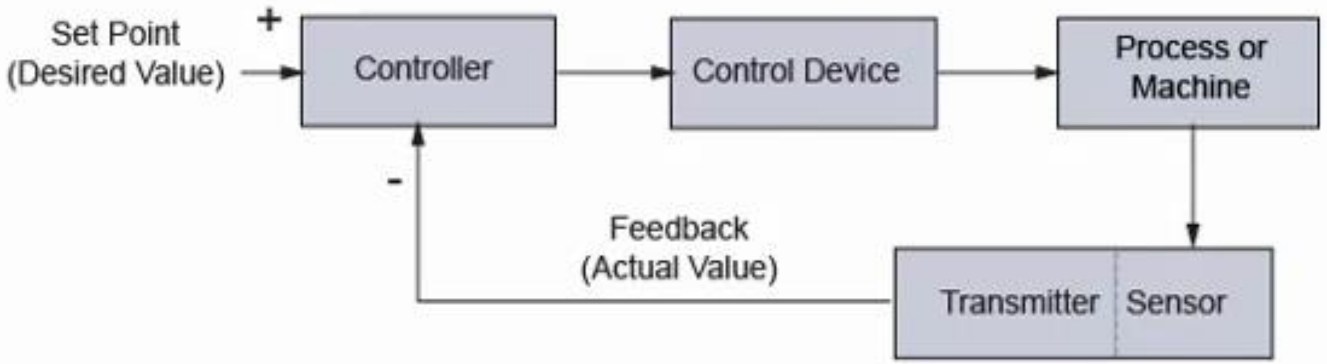
When additional network ports are required or when a different type of connection is needed, communication modules are added to the configuration.

Source: Siemens

PLC Hardware

Special Purpose Modules

Closed-Loop Control



PLCs are very fast and have many types of signal modules, but some tasks require special purpose modules. Many of these modules are designed for closed-loop control applications, which involve controlling a process or machine in response to a feedback signal from a sensor.

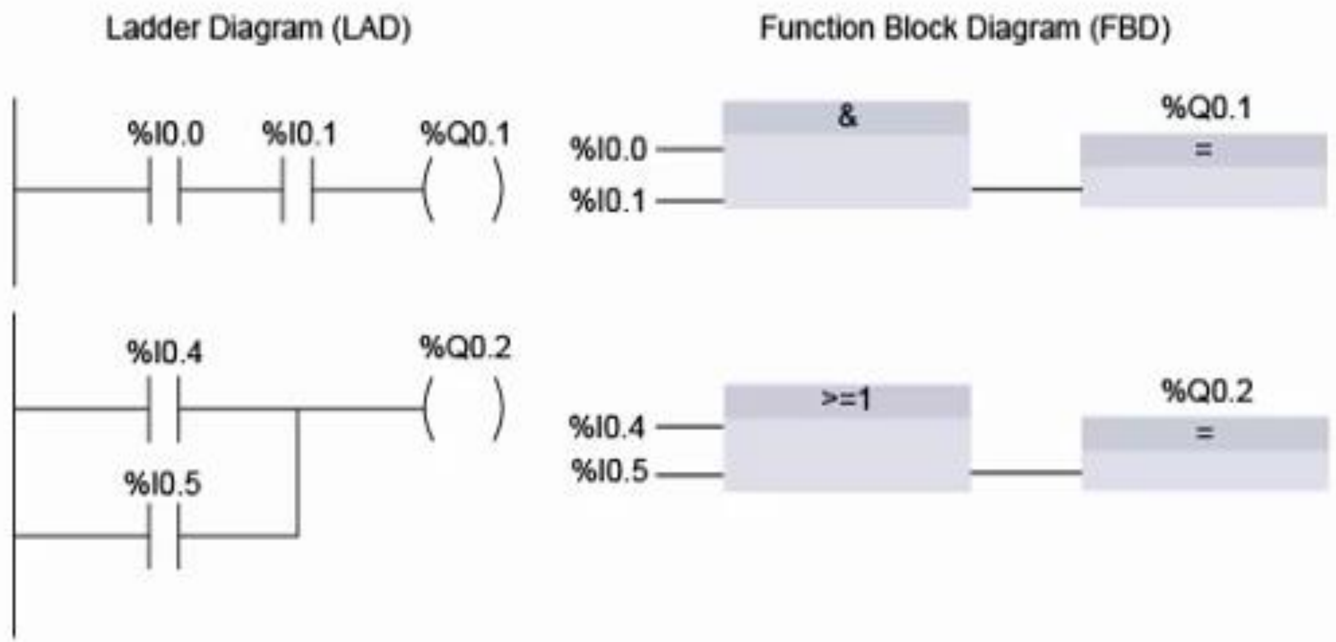
A control loop may require a special purpose module because of the type of sensor, control device, or algorithm used. A control algorithm is a set of rules or calculations that define the control process.

In addition to closed-loop control applications, PLCs use special purpose modules for counting or generation of high frequency pulses.

S7-1500 PLCs have technology modules for high-speed counting and measurement applications.

Source: Siemens

Programming Concepts



There are multiple ways to program a PLC. At one time, PLC programming languages varied with the PLC manufacturer. In general, however, PLCs manufactured in recent years are programmed using a language defined in an international specification, IEC 61131.

Two of the programming languages defined in this specification are ladder diagram (LAD) and function block diagram (FBD).

Source: Siemens

TYPES OF MECHANICAL DESIGN FOR PLC SYSTEMS

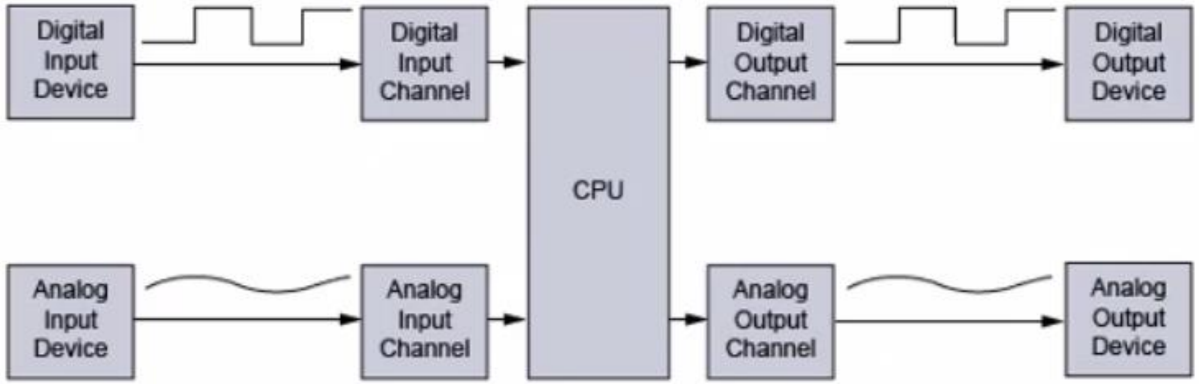
Programmable Logic Controller Brands:

- Compact / Standard / Single Box
- Rack Type / Modular

Inputs and Outputs

I/O Types:

Digital Inputs and Outputs
Analog Inputs and Outputs



Digital Signal:
O or 220 V meaning Low or High
Example: Photoelectric Sensor that measures object presence through IR Wave

Analog Signal:
Continuous Signal meaning 0 to 10V or 4 to 20 mA
Example: Ultrasonic Sensor that measures object distance though sound waves

Source: Siemens

INPUTS and OUTPUTS

COMMON INPUTS

Start Push Buttons

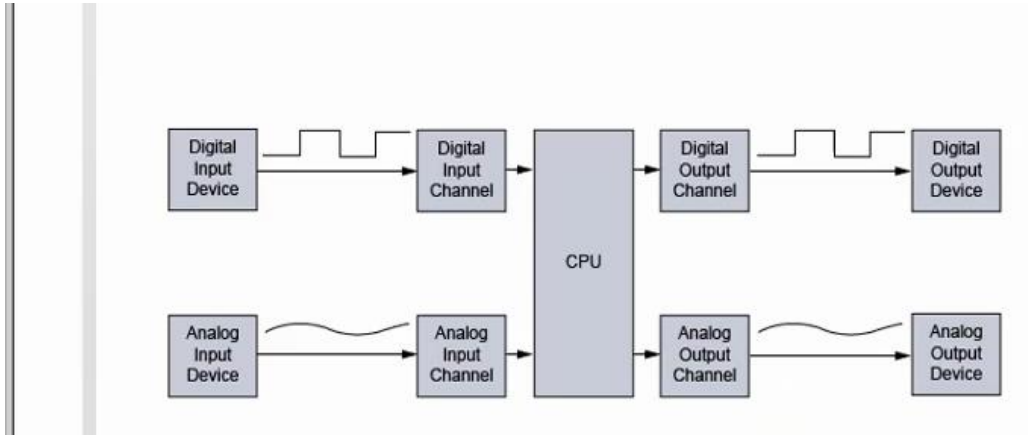
Stop Push Buttons

Emergency Stop Button

Selector Switch

Sensors (Limit Switches, Proximity, Ultrasonic, IR etc…)

Rating: 220VAC or 24VDC



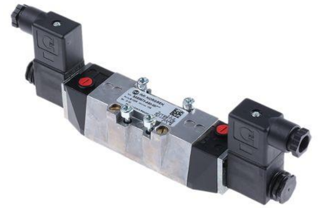
Rana Muhammad Awais | www.automationplay.com | automationplayonline@gmail.com | Facebook.com/automationplay | Youtube: Rana Muhammad Awais

INPUTS and OUTPUTS

COMMON OUTPTUS

Lamps

Motor



Valves

Rating: 220VAC or 24VDC

CRITERIA:

- Digital and/or Analog I/Os
- No. of Inputs/Outputs (I/Os)
- Any special requirements (Temperature, load cell etc)
- Size of control program
- Data-collecting requirements
- Future expansion

TIA Selection Tool

https://new.siemens.com/global/en/products/automation/topic-areas/tia/tia-selection-tool.html

Siemens PLC Series

S7-200

- Compact PLC with Onboard I/Os
- Micro PLC for lower performance range
- Software: Step 7 Microwin
- Cable/Interface: PPI / Profibus

S7-300

- Compact Or Modular PLC
- Medium and Low end performance range
- Software: Simatic Manager
- Cable/Interface: MPI / Profibus

S7-400

- High performance and medium range
- Modular PLC
- For Process automation
- DCS Applications
- Software: TIA Portal
- High and medium end performance
- Cable/Interfaces: MPI DP / Profibus DP
- Software: PCS7 Package

S7-1200

- Medium and Low end performance range
- Compact PLC with onboard I/Os
- Software: TIA Portal
- Cable: Ethernet
- High and medium end performance
- Profinet

S7-1500

- Advanced and Modular controller
- High and medium end performance
- Highest system performance
- Software: TIA Portal
- Cable / Interface: Ethernet / Profinet

ET-200 with integrated CPU

- Distributed I/O
- with or without CPU
- Modular PLC
- High and medium end performance
- Software: TIA Portal
- Cable/Interface: Ethernet / Profinet

Siemens PLC Series

SIMATIC S7-300 PLCs

S7-300 Compact (C) CPUs

SIMATIC S7-300 PLCs have a space-saving modular design. S7-300 CPUs are available in Standard, Compact (C), Failsafe (F), and Technology (T) versions.

S7-300 Compact CPUs, shown here, have on-board I/O and technology functions. The specific technology functions included depend on the CPU model, but high-speed counting and pulse generation are examples of functions included in all models.

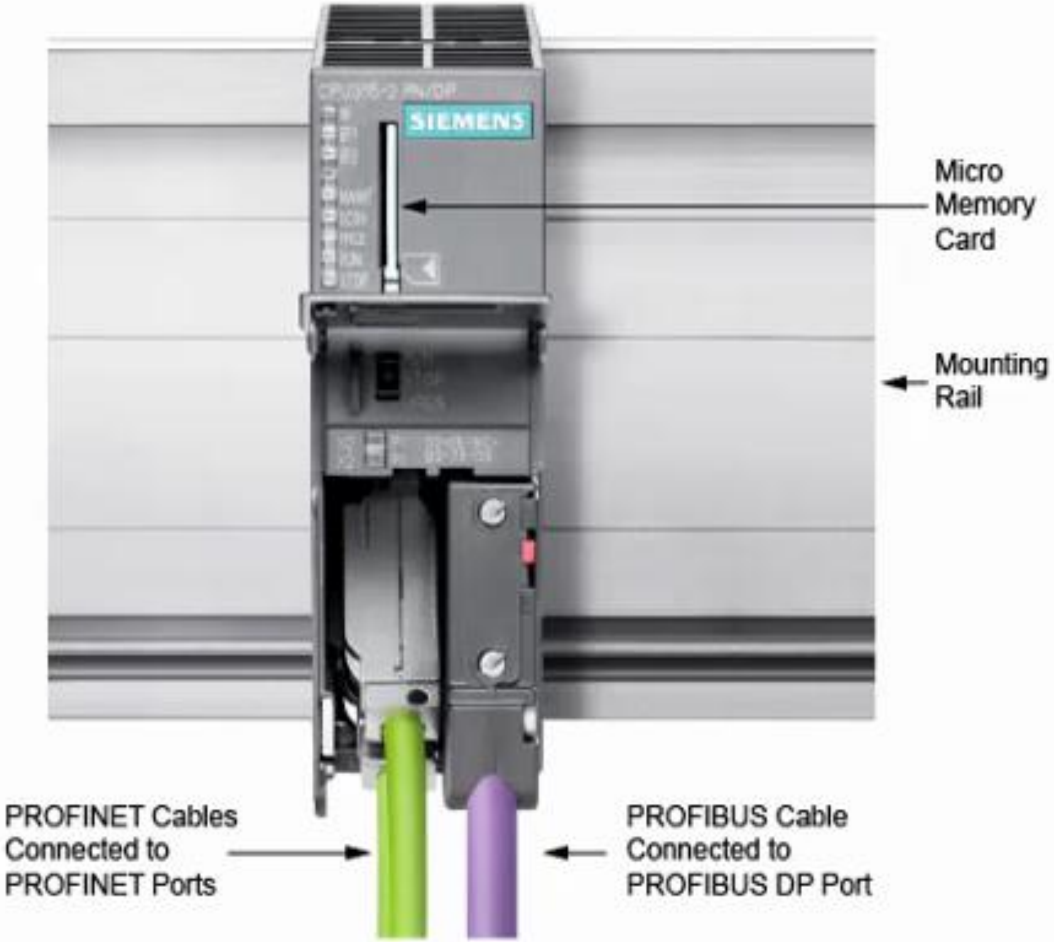
S7-300 Failsafe CPUs are used in applications where it is essential to guarantee the functional safety of machines or plants. They satisfy maximum safety requirements and comply with the relevant international standards.

S7-300 Technology CPUs have built-in features for motion control applications.

Source: Siemens

Siemens PLC Series

SIMATIC S7-300 PLCs



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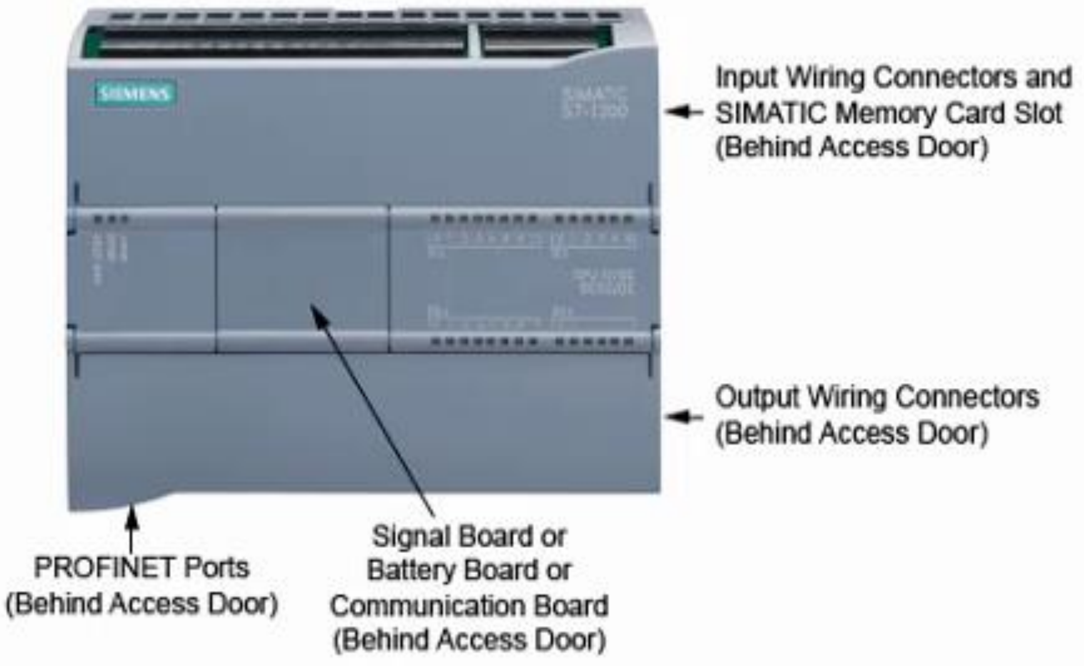
Source: Siemens

Siemens PLC Series

SIMATIC S7-1200 PLCs



CPU 1215C

SIMATIC S7-1200 PLCs have a compact configuration and can be used in a wide variety of applications. S7-1200 CPU models range from CPU 1211C to CPU 1217C.

When additional I/O is required beyond what is available on board and with the addition of a signal board, S7-1200 CPUs, except CPU 1211C, allow signal modules to be mounted to the right.

All CPUs can be equipped with up to three communication modules mounted to the left of the CPU.

All S7-1200 modules have built-in clips that allow easy and convenient mounting on a standard 35 millimeter DIN rail.

Signal modules have a bus connector on the front. Once a module is in place, the bus connector is moved to the left to allow the module to communicate with the CPU.

Source: Siemens

Siemens PLC Series

SIMATIC S7-1500 PLCs

S7-1500 PLC

SIMATIC S7-1500 PLCs provide extremely fast response times for optimal control quality and the highest system performance. SIMATIC S7-1500 CPUs are available in Standard and Failsafe (F) versions.

S7-1500 PLCs have a scalable configuration that incorporates a CPU, at least one system power supply module, multiple signal modules, and other modules as needed.

All S7-1500 CPU models feature an attached display for commissioning and diagnostics and have built-in PROFINET ports that permit the full range of PROFINET communication.

S7-1500 Failsafe CPUs, are used in applications where it is essential to guarantee the functional safety of machines or plants.

Source: Siemens

SIMATIC ET 200 with Integrated CPU

ET 200S

ET 200pro

Some SIMATIC ET 200 systems, ET 200S and ET 200pro for example, can include an interface module with an integrated CPU. The addition of a CPU makes an ET 200 a modular PLC.

SIMATIC ET 200S is a multifunctional, highly modular, compact I/O system. It has a rugged construction, allowing it to be used in conditions of high mechanical stress. Interface modules for this system in standard and failsafe designs are available with or without an integrated CPU.

SIMATIC ET 200pro is a small, extremely rugged, and high-performance I/O system with IP65, IP66, or IP67 protection. It does not require a control cabinet and can be mounted directly on the machine. Interface modules for this system are available in standard and failsafe designs with or without an integrated CPU.

Source: Siemens

Siemens PLC Series

Distributed I/O

A PLC I/O system can include components mounted near a CPU and components dispersed throughout a facility. PLC I/O system components mounted remote from the CPU are referred to as distributed I/O.

Many Siemens PLC models are designed to use SIMATIC ET 200 distributed I/O systems with network connections. These systems include some components designed for control cabinet mounting and other components designed for use without control cabinets. ET 200 systems include:

ET200S
ET 200MP
ET 200SP and ET 200ÍSP
ET200M
ET 200pro and ET 200pro IWUN
ET 200eco
ET 200eco PN

Source: Siemens

Siemens PLCs

Source: Siemens

Siemens S7-300

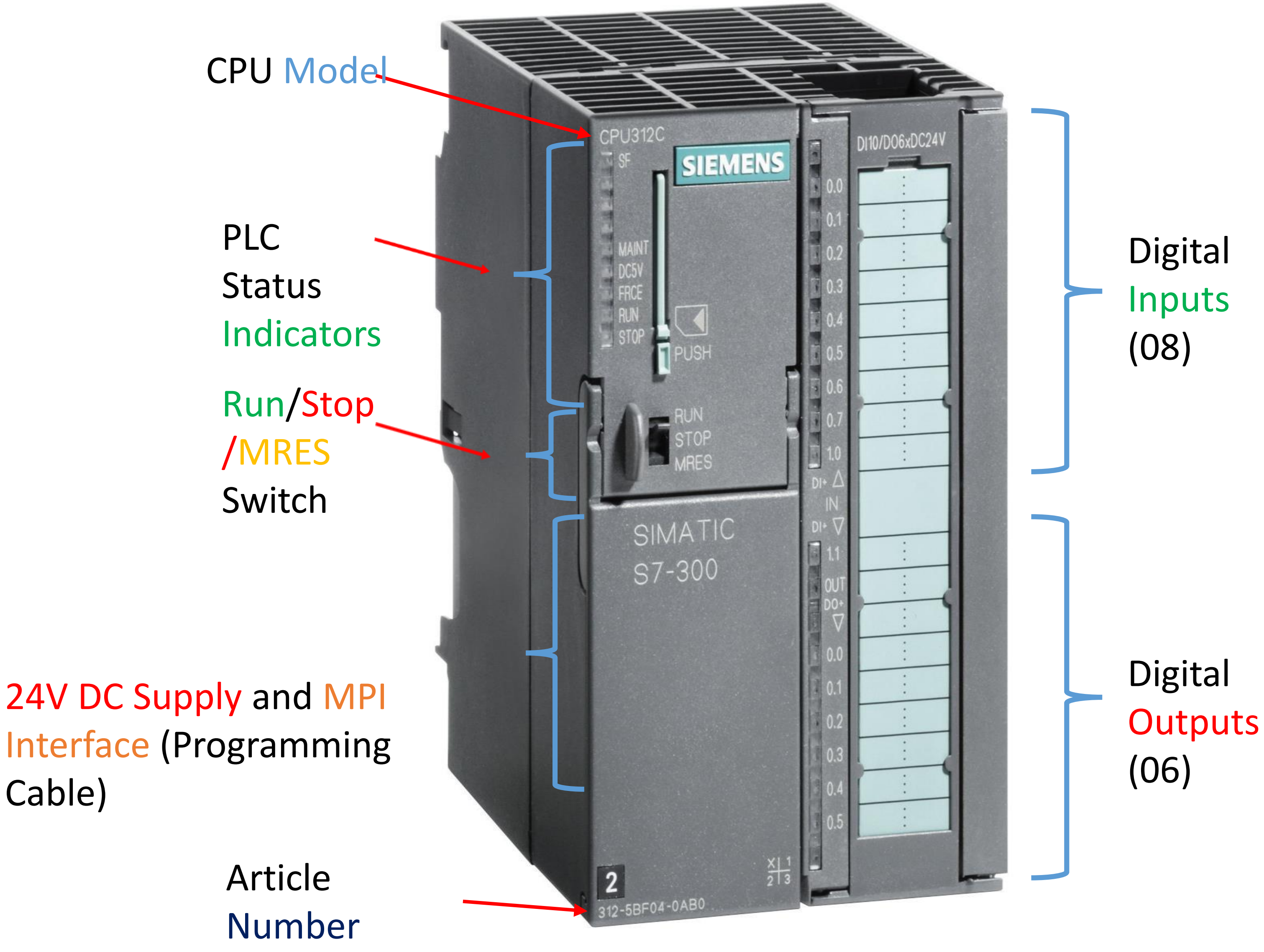
Siemens S7-300

Do you know?

S7 300 series is designed for Medium and Low end performance range

Specifications:

Net Weight: 0,458 Kg
Dimensions: 13,10 x 10,30 x 9,0010
I/O: DI/6 DQ,
2 high-speed counters (10 kHz) Integer
CPU Processing: 0.1 us for bit operation
MPI Interface
Programming:
Ladder/FBD/SCL/Graph/SCL
Software: STEP 7 V5.5 + SP1 or higher.



Siemens S7-1200

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CPU Processing: 0.1 us for bit operation
Ethernet Interface
Programming:
Ladder/FBD/SCL/Graph/SCL
Software: TIA Portal.

PLC Input and Output (I/O) System

Connections for 6 Inputs

Connections for 4 Outputs

The role of the PLC's input/output (I/O) system is to translate the signals received from input devices into low-voltage DC signals that the CPU can use and to perform the reverse operation when the CPU sends signals to output devices. In addition, the I/O system protects internal circuits from harmful voltage and current variations.

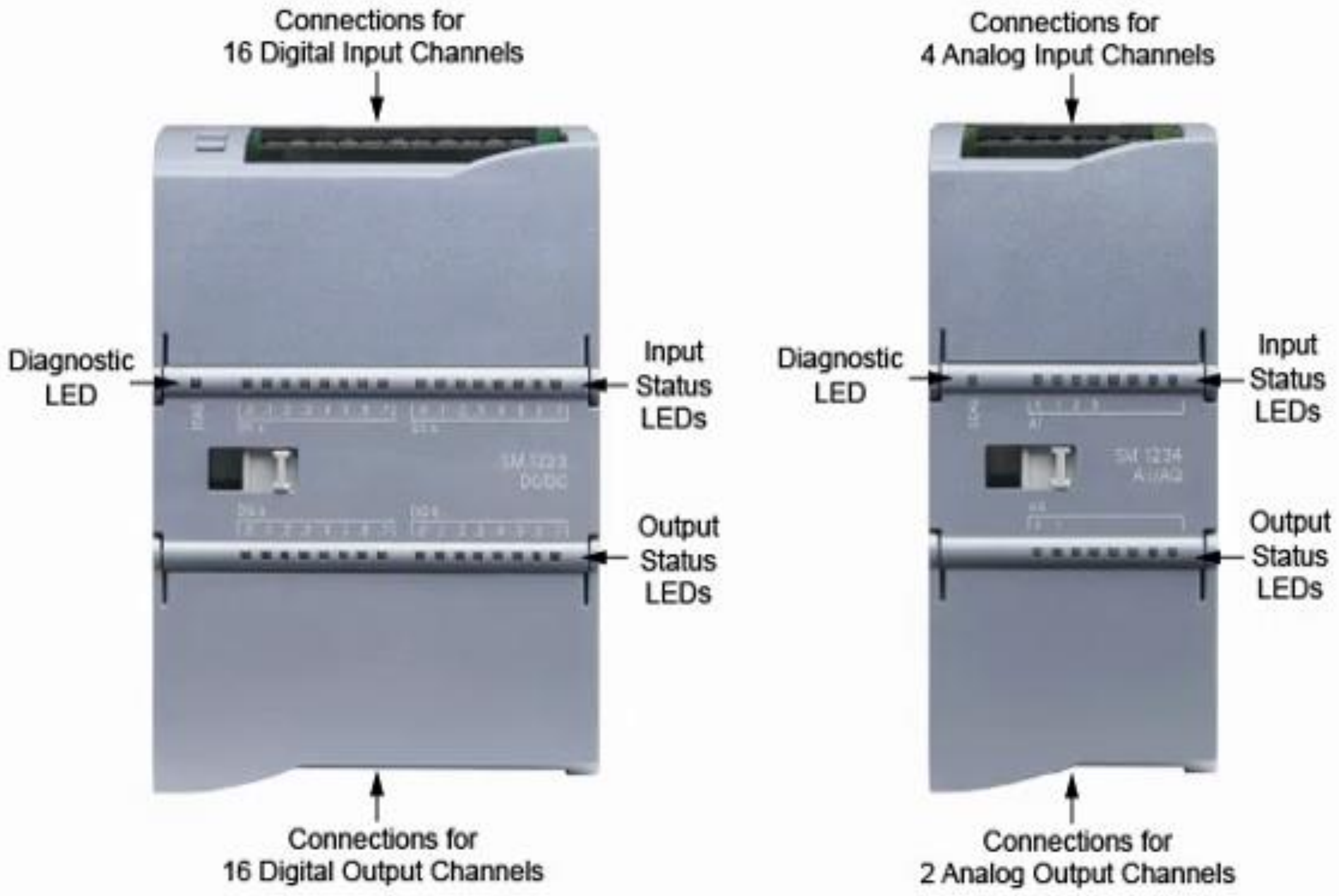
A small PLC may have some or all of its I/O channels in the same housing with the CPU.

Most Siemens PLCs, however, including the ones shown in the accompanying graphic, allow signal modules to be added.

Some or all of these modules may be close to the CPU, but signal modules can be remote from the CPU.

Source: Siemens

Signal Module Status Indicators



Signal modules have LED status indicators that are useful for system installation and troubleshooting. For example, the accompanying graphic shows two S7-1200 signal modules, a combination digital input/output signal module and a combination analog input/output signal module.

Both modules have a status LED for each channel. The digital channel status LED is green and turns on when the input or output is on. The analog channel LED is green when the channel has been configured and is active and red when there is a channel error.

Both modules also have a diagnostic LED that is green when the module is operational and red when the module is defective or non-operational.

Source: Siemens

Analog Outputs

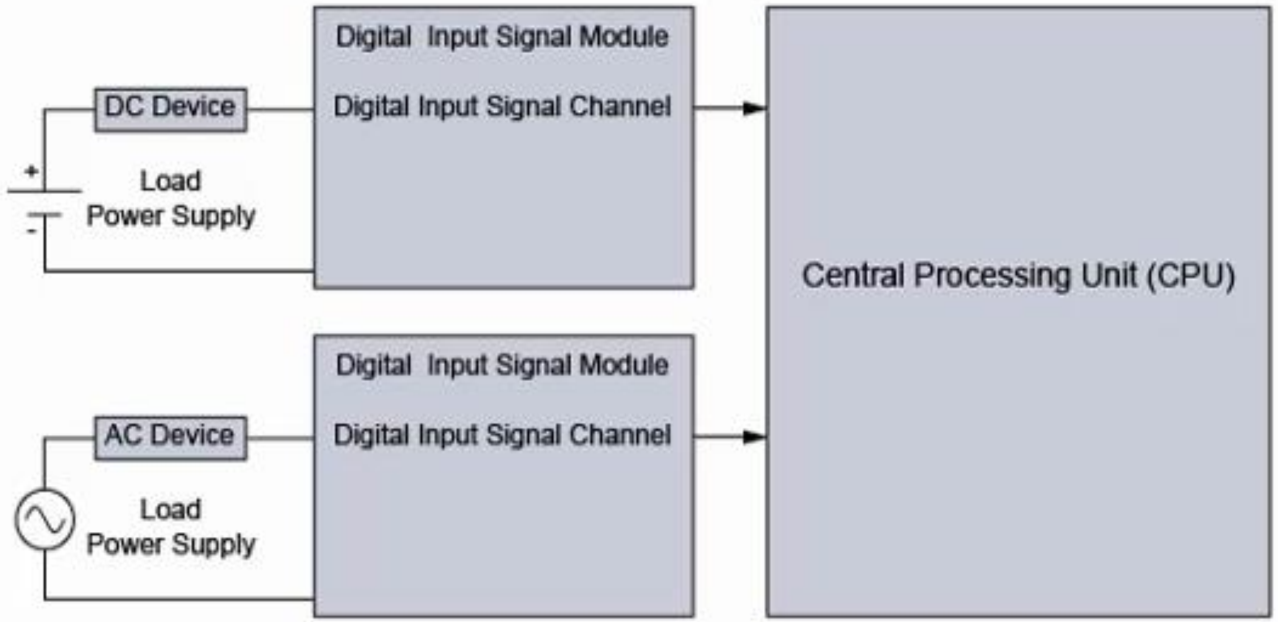
2 Channel Analog Output Module

When a CPU sends a numerical value to an analog output channel, the analog module converts the value to a voltage or current within the range set up for the output channel. The channel is typically connected to an analog output device that is controlling something in a machine or process, such as motor speed, valve position, or temperature.

PLC analog output signal modules vary in the number of output channels, channel resolution, and output signal types. The module shown in the accompanying graphic has two analog output channels. These channels can be set up for either the -10 to +10 volts range or the 0 to 20 milliamps range. The output resolution is 14 bits for the voltage range and 13 bits for the current range.

Source: Siemens

Digital Inputs



Some input devices use direct current (DC) and other input devices use alternating current (AC). The specifications for each device type also identify the level of voltage and current required by the device.

An additional consideration when matching a digital input signal module to a DC input device is the polarity of current flow.

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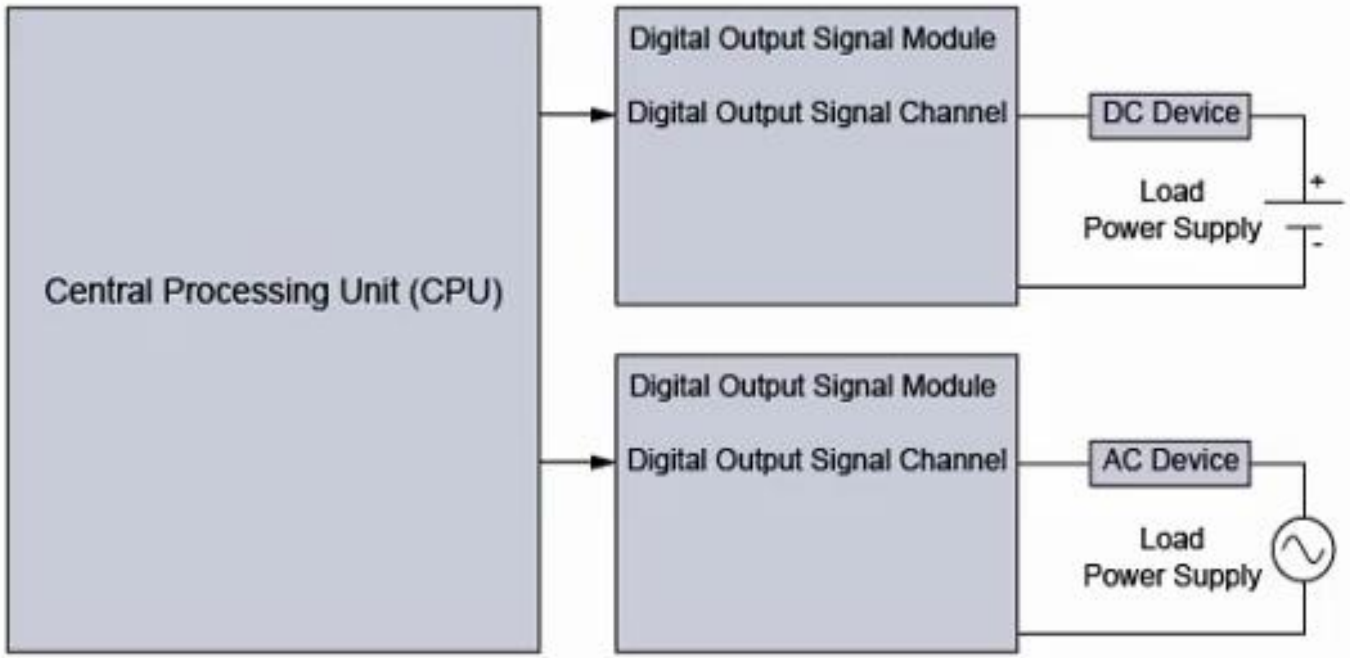
The S7-1200 PLC signal module shown in the accompanying graphic is designed to work with 24 VDC inputs and has connections for eight DC input channels, four on top and four on the bottom.

Note that this module allows the load power supply, which powers the input devices and circuits, to be connected with either polarity.

Source: Siemens

Digital Outputs



Some output devices use DC and other output devices use AC. Three categories of digital output signal modules are DC modules, AC modules, and relay modules.

AC output signal modules typically operate with a load power supply of 120 or 230 VAC or may be capable of operating with either source.

For a DC output signal module it is important to observe proper power supply polarity when making connections.

Relay output signal modules offer the advantage of being able to work with either AC or DC devices as long as the devices operate within the module's specifications and the switching speed required is not too fast.

Source: Siemens

Siemens S7-1200

<u>Siemens S7-1200</u>

Do you know?

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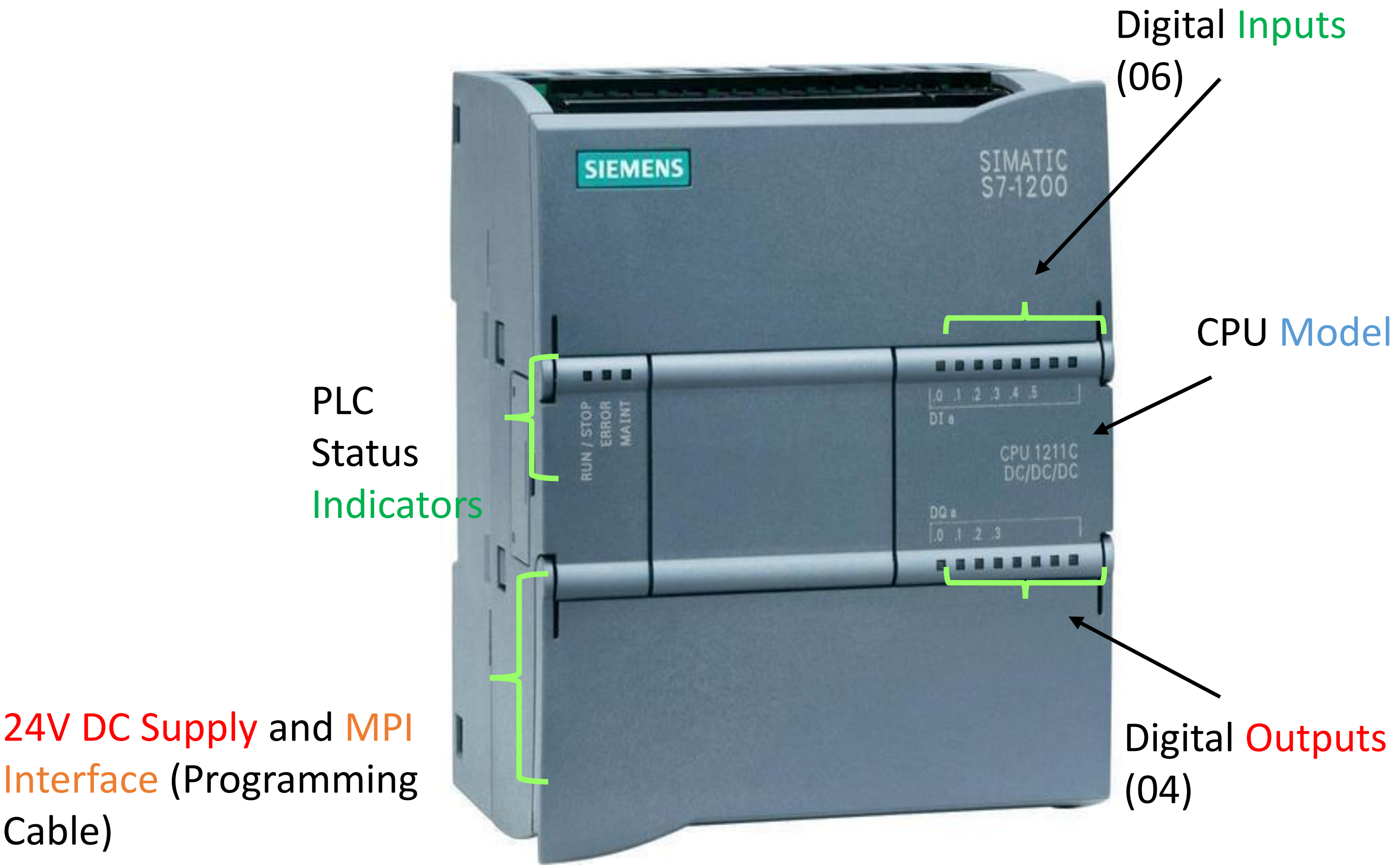


Setting up PLC

MPI Cable

SIMATIC MANAGER SOFTWARE

Setting up PLC

Industrial Ethernet (Profinet)

TIA PORTAL

subnet

Node

IP Address: 192.168.0.1
Subnet Mask: 255.255.255.0

subnet

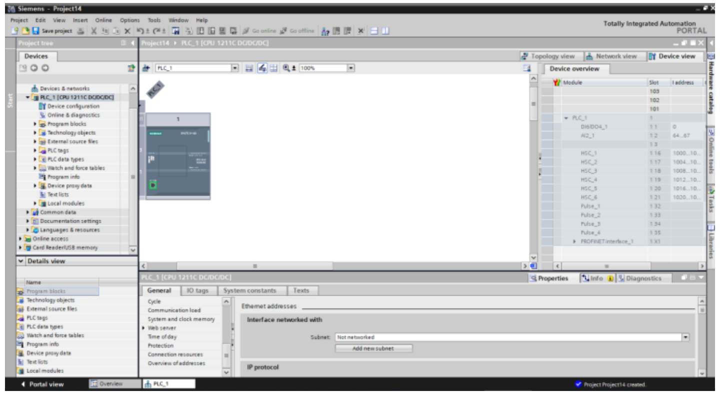
Node

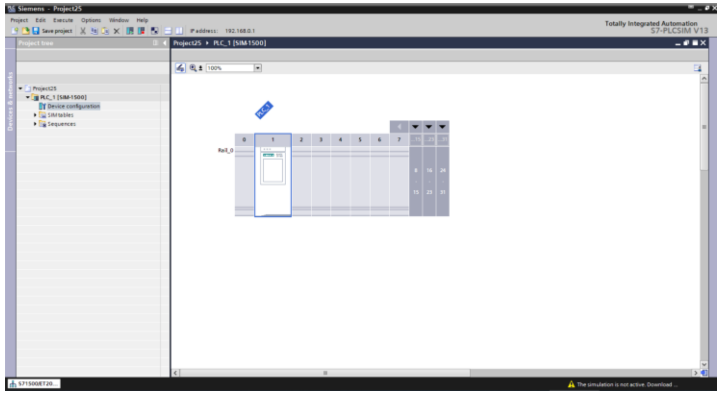
IP Address: 192.168.0.100
Subnet Mask: 255.255.255.0

Software

- Consistent Look & Feel for all programming editors
- Flexible screen layout for optimized work area
- Graphical network and device configuration
- Integration of PLC, HMI, Drives, and Safety in one engineering framework
- Reuse of project components with Global Libraries
- Integrated System Diagnostics
- Motion integration
- Optimized tag handling across PLC, HMI, and drives
- Trace functions
- Project-wide cross-referencing informa-tion, for fast troubleshooting, for instance
- Complete simulation of PLC and HMI
- Scalability across all product platforms
- Easy migration of existing systems

Simulating Siemens S7-1200 PLC





TIA Portal (v15)
Programming Software
for Siemens PLCs

S7-PLCSIM (v15)
For Simulating Programs
without PLC

SIEMENS
PLC Communication Methods

In English and Urdu

Instructor: Rana Muhammad Awais

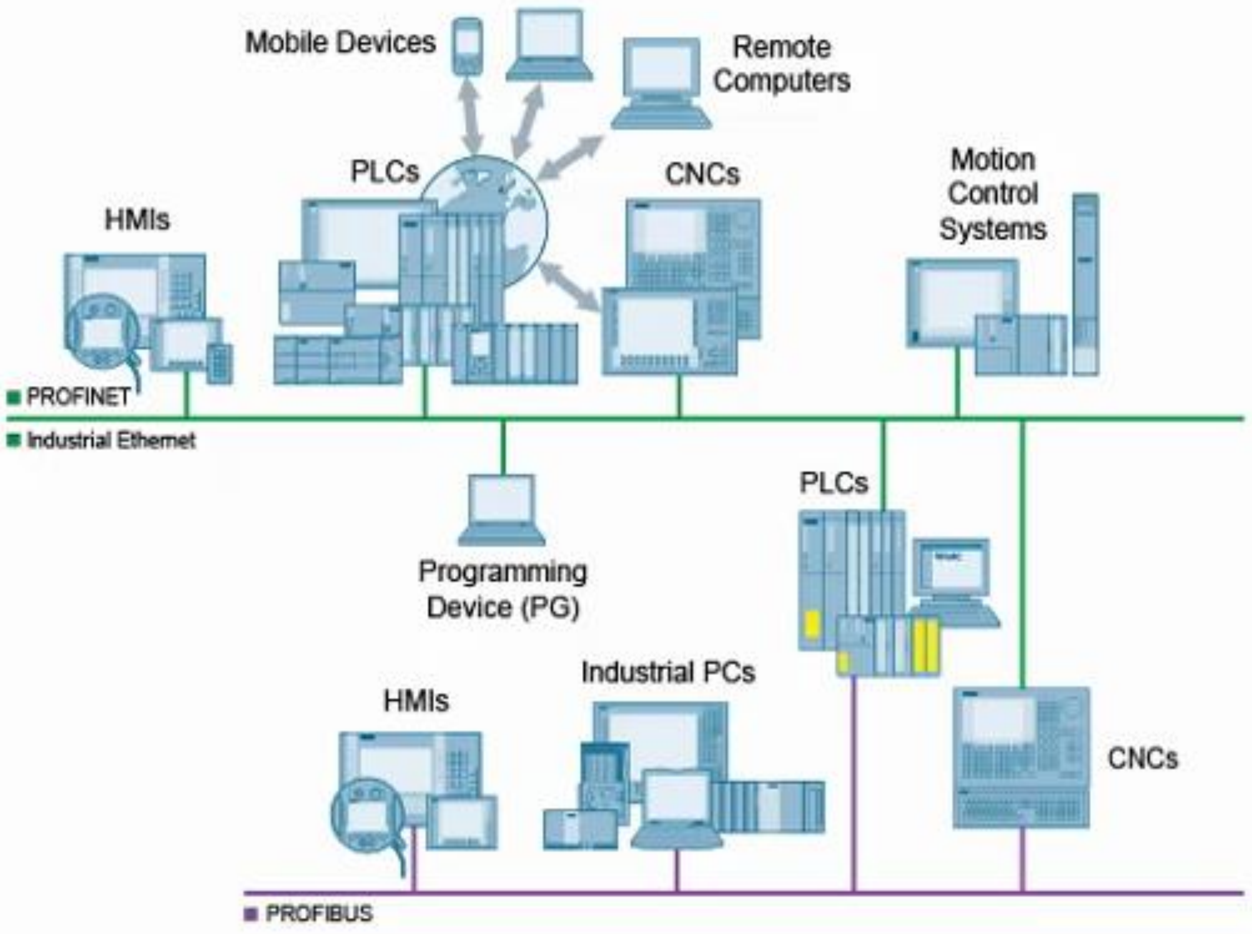
AUTOMATION PLAY

SIEMENS
Ingenuity for life

MINDSTORM ENGINEERING
IDEAS THAT MATTER

Siemens PLC Communication

PLC Communication



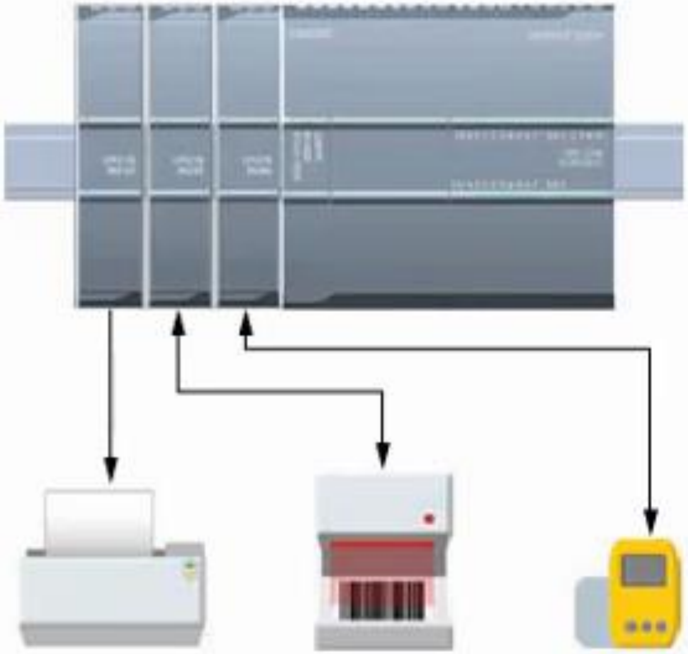
Communication is central to what a PLC does. Therefore, understanding communication concepts is critical to understanding PLCs.

PLCs communicate with many other devices and systems in various ways. In some situations a PLC connects directly to another device.

Often, however, various components of an automation system, including PLCs, are interconnected using network technologies.

Source: Siemens

Serial Communication



Serial communication is the most basic form of data communication used by PLCs because it involves transmitting data one bit at a time on a signal line and receiving data in the same fashion on another signal line, or in some cases the same line.

A PLC uses serial communication with a variety of devices such as personal computers, printers, RFID readers, and barcode scanners.

Serial communication uses interface standards such as RS-232, RS-422, and RS-485 that identify the signal lines available for communication.

Connecting a PLC to another device via an RS-232, RS-422, or RS-485 interface, often requires a communication module.

Source: Siemens

Industrial Networks

In most factories, the need for rapid information flow is critical. This often requires intelligent devices such as PLCs, drives, computers, HMIs, and some actuators and sensors to be interconnected by one or more local area networks (LANs).

A LAN is a communication system designed for private use in a limited area. U\Ns used in industrial applications must be able to operate reliably in conditions that are unsuitable for office equipment.

The topology of a network is the pattern formed by network devices. Examples of network topologies include star, tree, linear, ring, and combined topologies. Some networks allow all of these topologies and other networks are more limited in the types of topologies available.

Source: Siemens

Siemens PLC Communication

Network Cables

Two types of cables used for Industrial Ethernet, including PROFINET, are shielded twisted pair cable and fiber optic cable.

Shielded twisted pair cable consists of twisted pairs of copper wires with a layer of braided wire between the outer plastic jacket and the inner conducting wires to provide protection from external sources of electrical noise.

Fiber-optic cable is recommended for use in applications with high levels of electrical noise, where grounding problems exist, or where electrical isolation is needed. These cables are also used in open-air systems or where no electromagnetic radiation is permitted.

PROFIBUS networks also use various types of shielded twisted pair cables. AS-Interface networks use a two-wire cable that caries both data and power.

Source: Siemens

PROFIBUS DP

CPU 1516-3 PN/DP

Communications module CM 1542-5

A fieldbus is an industrial network used for distributed control, and the most popular fieldbus is PROFIBUS. The two most common forms of PROFIBUS are PROFIBUS DP, for factory automation, and PROFIBUS PA, for process automation.

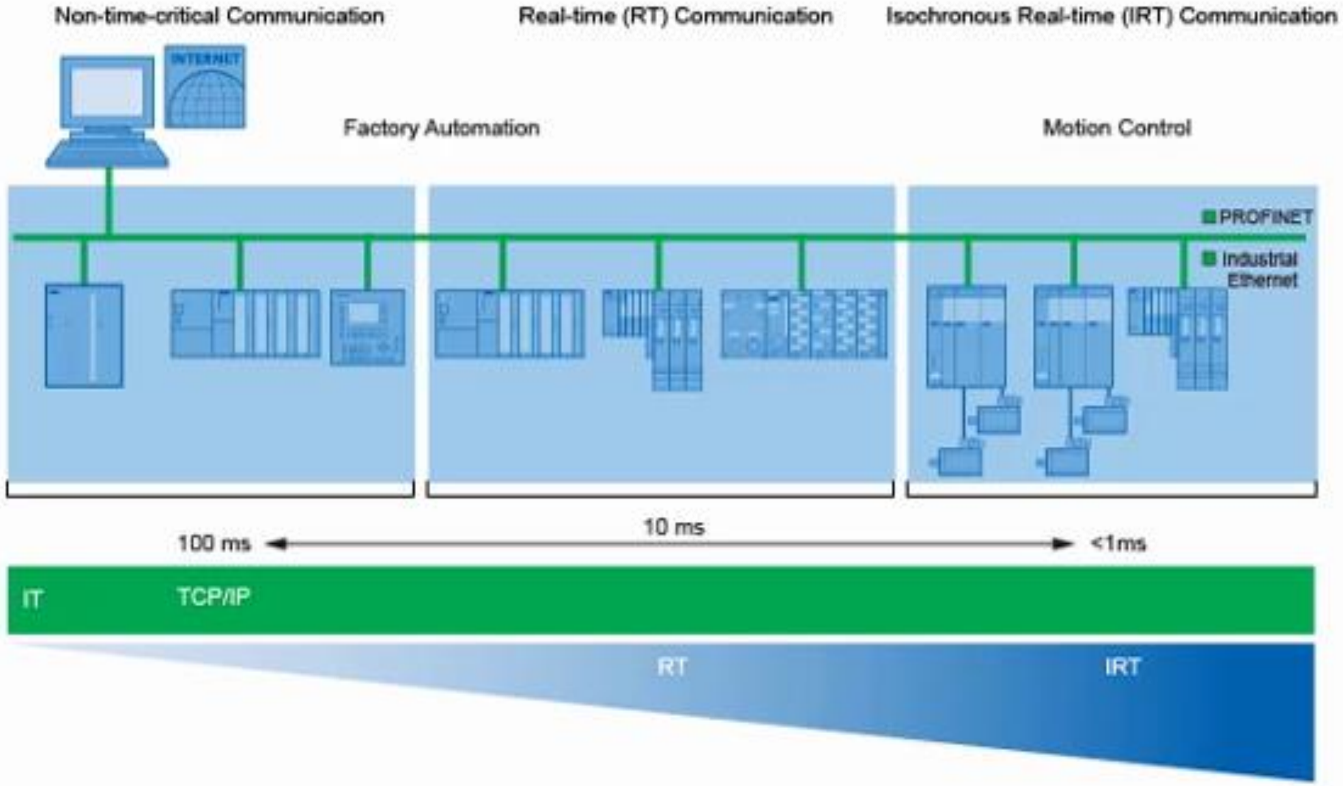
PROFIBUS is a master-slave system. A slave device communicates only when requested to do so by its master device. A PROFIBUS master can control up to 125 slaves connected to the master in a linear topology. PROFIBUS uses copper or fiber optic cables, but infrared communication is also supported. PROFIBUS has a maximum data rate of 12 Mbps.
PROFIBUS has two classes of master devices.

Most communication is handled by a class 1 master. A class 2 master is used for configuration, maintenance, and diagnostics and can communicate with class 1 masters and their slaves.

Source: Siemens

Siemens PLC Communication

PROFINET



PROFINET is the open Industrial Ethernet standard of PROFIBUS & PROFINET International and the leading Industrial Ethernet standard.

PROFINET 10 extends the benefits of standardized, Ethernet communication to distributed field devices by simultaneously handling three communication performance levels: non-time-critical communication, real-time (RT) communication, and isochronous real-time (IRT) communication.

PROFINET allows field devices from many suppliers to be easily connected to the network. PROFINET also protects investments in existing networks by simplifying their integration into a factory-wide network. In a PROFINET system, the number of devices is not restricted. PROFINET uses copper or fiber optic cables, but also supports IWLAN communications.

Source: Siemens

Siemens PLC Communication

PROFINET Device Types

Devices on a PROFINET Network are connected through a switch. Siemens offers a variety of stand-alone network switches, and many Siemens control devices have a built-in switch with one or more PROFINET ports.

The following PROFINET device types are shown in the accompanying figure.

IO Controller
IO Device
IO Supervisor
Proxy

These PROFINET device types have been part of the standard since its inception.

Later innovations to PROFINET IO include the following device types: Shared Device and I Device.

Source: Siemens

Siemens PLC Communication

PROFINET Profiles

PROFINET IO
- Integration of distributed field devices via Industrial Ethernet

PROFIdrive

PROFIsafe

PROFIenergy

Profiles are open and vendor-neutral, allowing users to incorporate products from multiple suppliers into their systems without concern for interoperability.

The PROFIdrive profile allows users and OEMs to design machines and processes with drives from multiple suppliers communicating via PROFIBUS or PROFINET.

PROFIsafe is an integrated safety technology applicable for both discrete manufacturing and process automation which permits the transmission of standard and safety-related data on a single bus cable.

The use of PROFIenergy configurations enables substantial energy savings without a reduction in productivity.

Source: Siemens

Industrial Ethernet

Industrial Ethernet uses industrial switches to provide the performance and reliability needed for high-speed factory networks.

Industrial Ethernet allows communication speeds up to 100 Mbps with full-duplex operation, which means that network devices can simultaneously send and receive data.

The Siemens SIMATIC NET product family includes SCALANCE Industrial Ethernet switches designed to fit varied requirements from localized to plant-wide networks.

Siemens FastConnect system includes cables and connectors designed for demanding factory applications and assembly tools designed to speed installation.

Source: Siemens

Wireless Communication

Wireless network devices send and receive signals through the air. Wireless networks are used where devices must be mobile or where it is too expensive or difficult to run cables.

Wireless networks are also used where the controlled equipment must be mobile, such as with automated guided vehicle systems, overhead monorails, and cranes.

One of the most popular types of factory wireless networks is I WLAN, which stands for Industrial Wireless Local Area Network. I WLAN uses devices with antennas to transmit and receive radio wave signals.

This includes RCoax radiating cables, one of which is shown in the foreground in the accompanying graphic. RCoax cables are used as antennas from I WLAN access points.

Source: Siemens

Siemens PLC Series

Actuator Sensor Communication

AS-Interface (AS-i) is an open, low-cost network that simplifies the interconnection of actuators and sensors with controllers. AS-i replaces the complex wiring and proprietary interfaces often used for this interconnection with only two wires which transfer both data and power. In an AS-i network, a master communicates with up to 62 slaves through a cyclic polling process. The master is often a PLC with a communication module.

IO-Link is another actuator-sensor communication system. IO-Link is a point-to-point system, not a fieldbus. It uses a three-wire cable, 24 VDC power supply, and an IO-Link master. Depending on the master, up to 16 devices per master are allowed. The accompanying graphic shows two examples of IO-Link masters and some of the many IO-Link slave devices that can be used with Siemens PLCs.

Source: Siemens

SIEMENS
PLC Programming

In English and Urdu

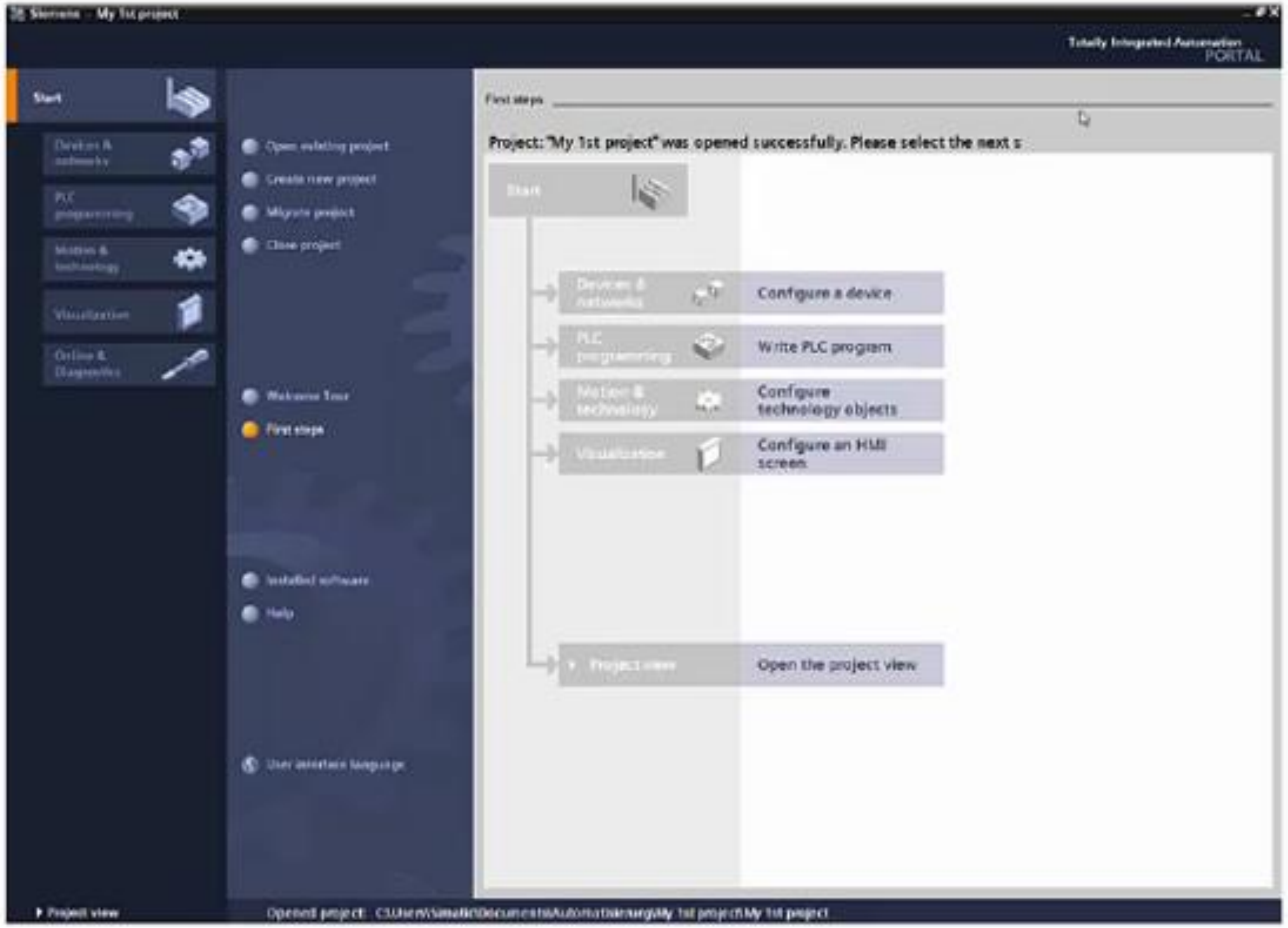
Instructor: Rana Muhammad Awais

AUTOMATION PLAY

SIEMENS
Ingenuity for life

MINDSTORM ENGINEERING
IDEAS THAT MATTER

TIA Portal



Siemens Totally Integrated Automation Portal (TIA Portal) software is used in all phases of automation system design, operation, and maintenance. TIA Portal combines the software editors needed for these various tasks in one engineering tool.

In portal view, the available tasks are clearly identified, such as "Create new project", "Configure a device" or "Write PLC program."

Selecting "Configure a device" allows the user to quickly and easily set up a new device. Device types are easily located in a searchable hardware catalog.

Configuration can be further simplified by using TIA Portal to detect connected devices. For example, the accompanying graphic shows a TIA Portal project view after an S7-1200 PLC has been detected.

Source: Siemens

Siemens PLC Series

SIMATIC STEP 7 Engineering Software

For Siemens PLCs, the following engineering software is used to perform these functions.

S7-200 PLCs require STEP 7 Micro/WIN

S7-300 and S7-400 PLCs require STEP 7 Professional (TIA Portal) or STEP 7 Professional

S7-1200 PLCs require STEP 7 Basic (TIA Portal) or STEP 7 Professional (TIA Portal)

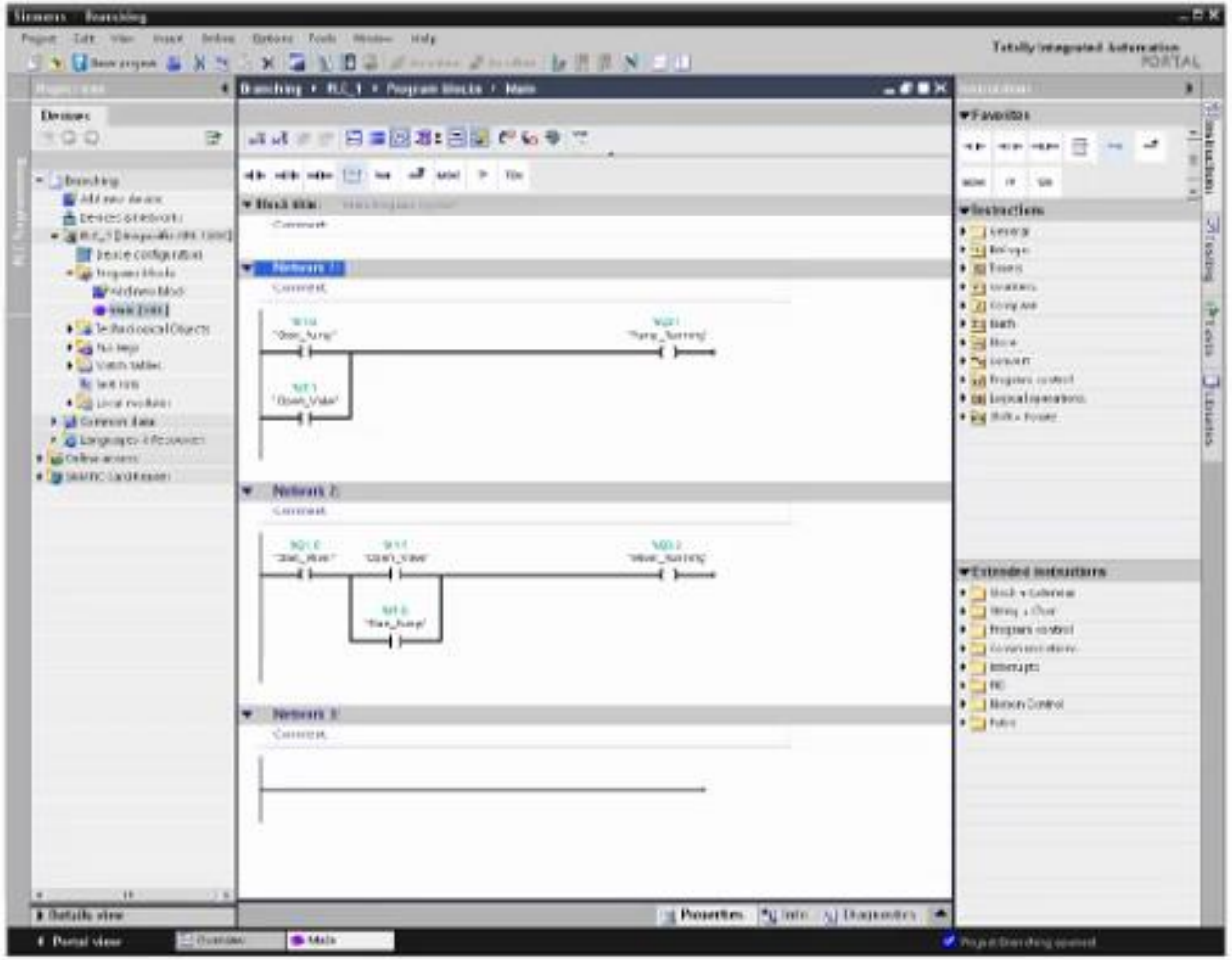
S7-1500 PLCs require STEP 7 Professional (TIA Portal)

STEP 7 engineering software runs on a personal computer (PC) that has a Microsoft Windows operating system. Siemens sells a variety of industrial PCs that can be used as programming devices.

Source: Siemens

Siemens PLC Series

SIMATIC STEP 7 Basic (TIA Portal)



STEP 7 Basic (TIA Portal) is used for the configuration and programming of S7-1200 PLCs and related devices. This can also be done using STEP 7 Professional (TIA Portal); however, STEP 7 Basic is a more economical approach when other PLC models are not being used. STEP 7 Basic supports the following IEC 61131 programming languages:

Ladder diagram (LAD)
Function block diagram (FBD)
Structured text, also known as structured control language (SCL)

STEP 7 Basic allows program elements to be dragged and dropped into the program and the logical arrangements of these elements to be modified in the same way.

As shown in the accompanying graphic, a user program for an S7-1200 PLC can include a full range of instructions.

Source: Siemens

SIMATIC STEP 7 Professional (TIA Portal)

STEP 7 Professional (TIA Portal) is used for the configuration and programming of S7-300, S7-400, S7-1200, and S7-1500 PLCs and related devices.

Because S7-300 and S7-400 PLCs were developed prior to the introduction TIA Portal software, aversion of STEP 7 Professional separate from TIA Portal is also available for use with these PLCs.

In addition to the LAD, FBD, and SCL programming languages included in STEP 7 Basic, STEP 7 Professional includes :

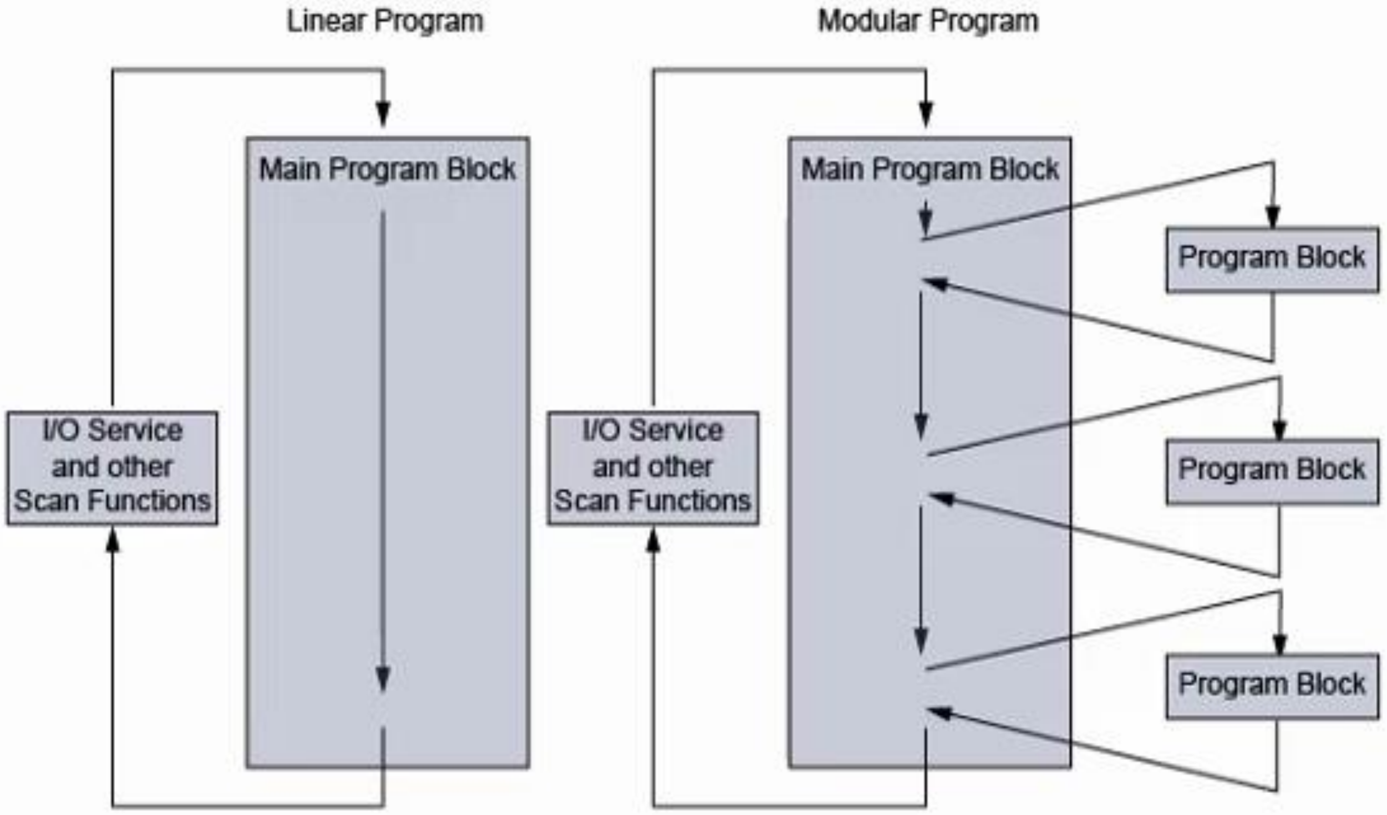
Statement list (STL) also known as Instruction list (IL).

Sequential function chart (SFC) included in STEP 7 Professional as S7-Graph.

STEP 7 Professional also includes S7-PLCSIM software.

Source: Siemens

Modular Programming



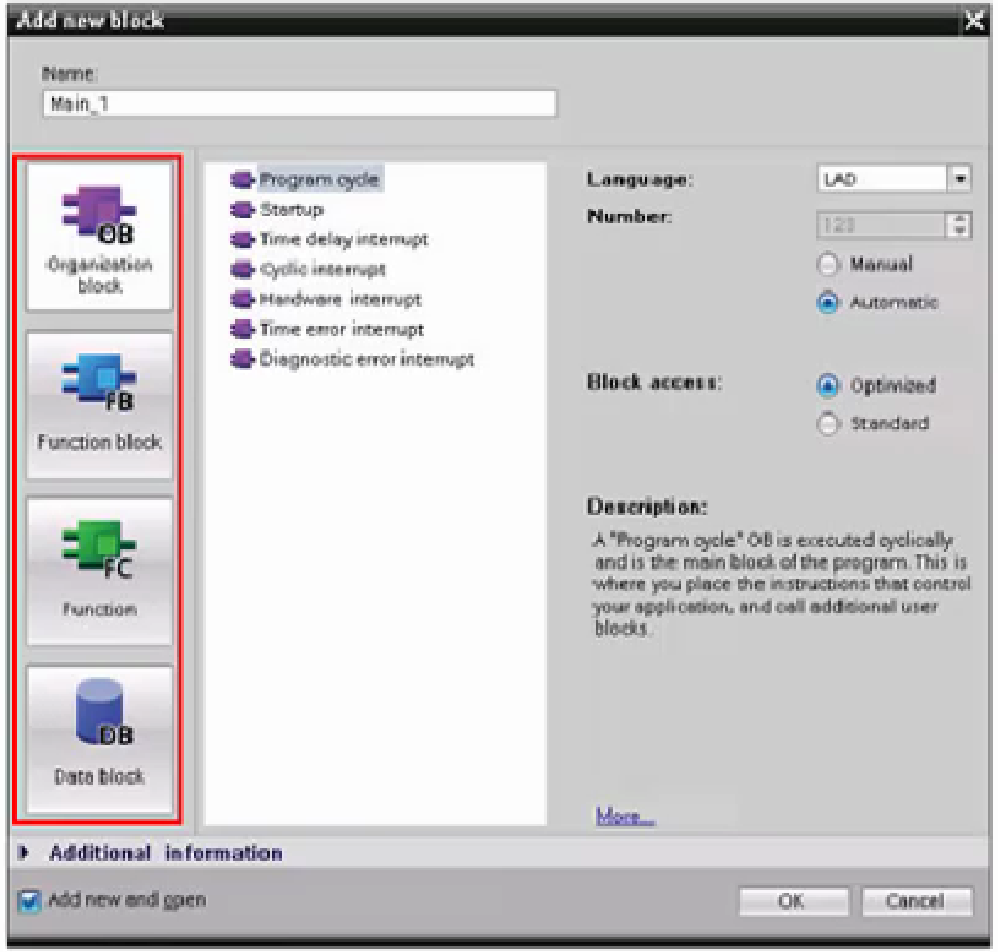
A PLC program can be organized as a linear program or a modular program. As shown on the left in the accompanying graphic, a linear program has all the instructions in one block and executes these instructions in sequence in each PLC scan.

A modular program is composed of multiple program blocks. Some program blocks are executed in each PLC scan and other program blocks are executed under special circumstances.

As shown in the accompanying figure, program blocks can also be nested. This means that one program block can call another program block which can call another program bock. This provides additional flexibility in programming.

Source: Siemens

Program Blocks



An S7 PLC program can include data blocks (DBs) and three types of program blocks:

Organization blocks (OBs)
Function blocks (FBs)
Functions (FCs)

OBs define the structure of the program. Every program must have at least one OB. If it has only one OB, that block is identified as OB1.

FCs and FBs contain the program code that performs specific tasks. An FB uses an instance DB or a global DB. An FC cannot have an instance DB.

A common modular program application involves one PLC controlling multiple machines or devices with the same functionality.

Source: Siemens

CPU Memory

S7 CPUs have the following memory areas: load memory, work memory, retentive memory, local memory, and global memory.

Load memory stores all code blocks, data blocks, technology objects, and hardware configuration. Load memory is retentive memory.

The CPU copies some elements of the user program from load memory into work memory during program execution. Work memory is volatile memory.

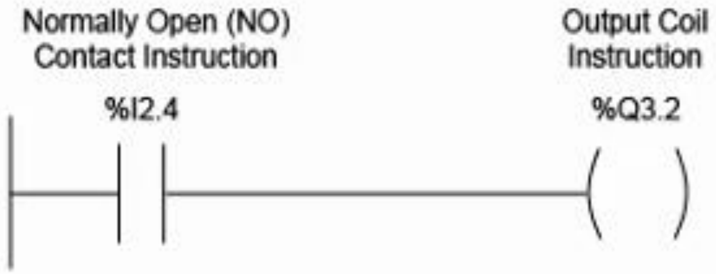
Retentive memory is non-volatile memory for saving a limited quantity of data.

Local memory (L) is temporary memory used during the processing of a program block.

Global memory includes bit memory and image tables for inputs and outputs.

Source: Siemens

Assigning CPU Memory Areas to instructions



Most instructions in a PLC program interact with one or more bits, bytes, or words in the CPU memory. The specific memory locations used are identified by operands.

This type of operand is called an absolute operand and is preceded by the % symbol when displayed in STEP 7 (TIA Portal).

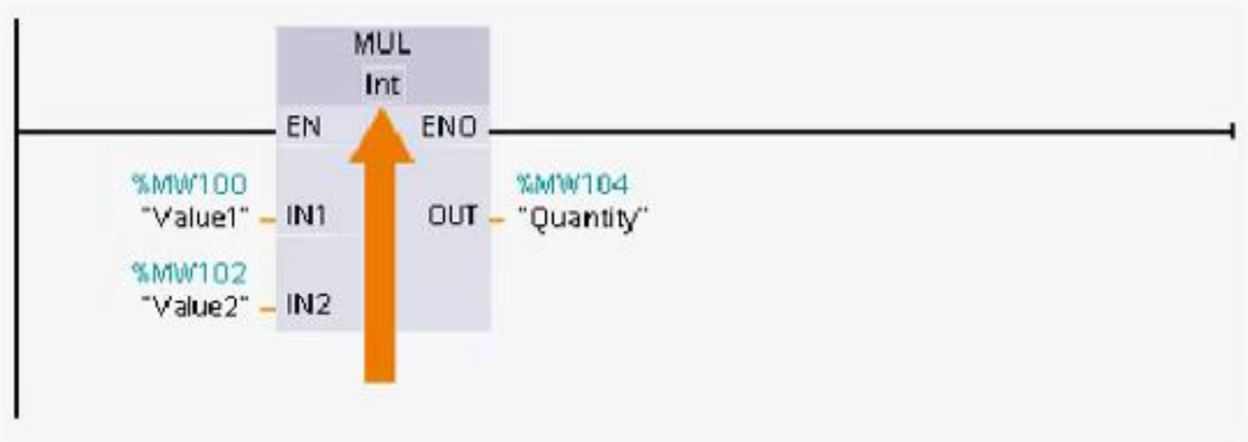
STEP 7 also allows use of alphanumeric tags as operands. A tag preceded by # is assigned to one program block. A tag enclosed in quotation marks is available to any program block.

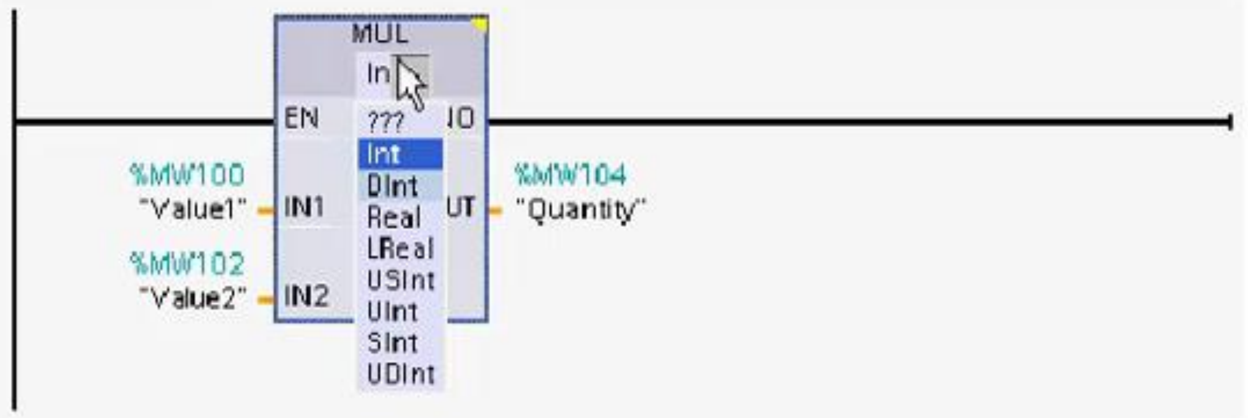
One way a tag can be created is by assigning it to an instruction in the user program and then dragging the tag to the associated input or output in the device view.

A tag can also be created by entering it into the PLC tag table directly and then dragging the tag to an input or output.

Source: Siemens

Data Types





To determine how an instruction in a PLC program interprets bits in the locations designated by the instruction's operands, you must know the data type the instruction assigns to these bits.

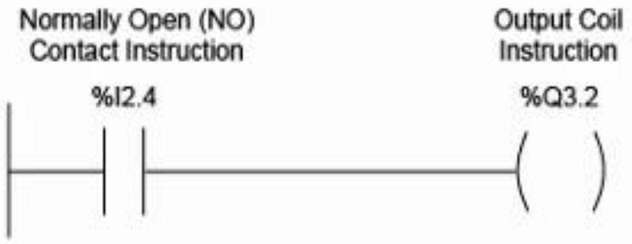
There are many data types, and they are often represented by shorthand names.

PLC data types of various lengths are specified for binary numbers, integers, floating point numbers, date and time, characters, parameters, system data, and other types of data. Because the number of data types has increased over time, not all data types are available for all Siemens PLCs.

The accompanying table shows the binary number, integer, and real number data types available for some modular Siemens PLCs. Additional information on these and other data types is available in the documentation for each PLC model.

Source: Siemens

Bit Logic Instructions

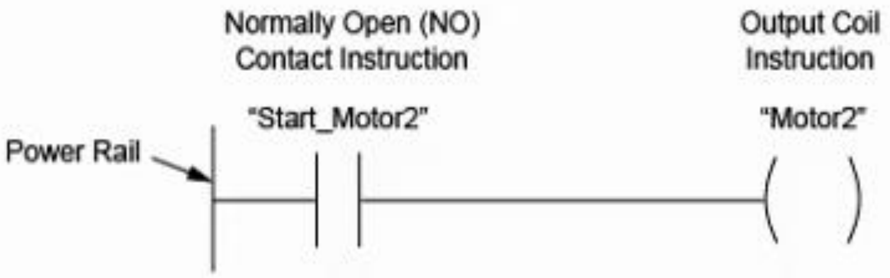


One of the ways that PLCs use binary bits is to represent the on or off condition of inputs and outputs. Within an S7 PLC CPU there is a portion of memory referred to as the process image. The process image has a bit assigned to every possible input and output.

Input (I) and output (Q) bits in the process image along with a type of memory called bit memory (M) are collectively called global memory. Instructions that perform logical operations using single-bit memory locations are referred to as bit logic instructions.

Because the LAD programing language includes many instructions, STEP 7 groups instructions into categories. As the accompanying graphic shows, there are a number of basic and extended instruction categories. This lesson provides examples of some of the instructions in the bit logic category.

Power Flow



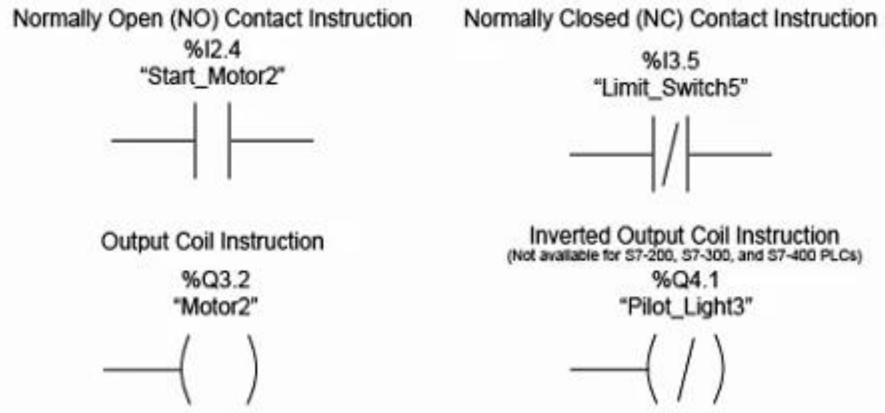
Even though a network in a LAD program is an arrangement of computer instructions, each network is said to control power flow from the power rail. In programming terminology, this examination of logical conditions is called solving the logic and the solution of a configuration of instructions is called the result of logic operation (RLO).

For the upper network, the normally open Start_Motor2 contact instruction is in parallel with the normally open Motor2 contact instruction, and power must flow through one or both of these contact instructions to get to the Stop_Motor2 normally open contact instruction. Then, the Stop_Motor2 normally open contract instruction must permit power flow in order for the Motor2 output coil instruction to turn on.

Although the lower network in the accompanying graphic has different connections, the logical solution to both networks is the same.

Source: Siemens

Contact and Coil Instructions



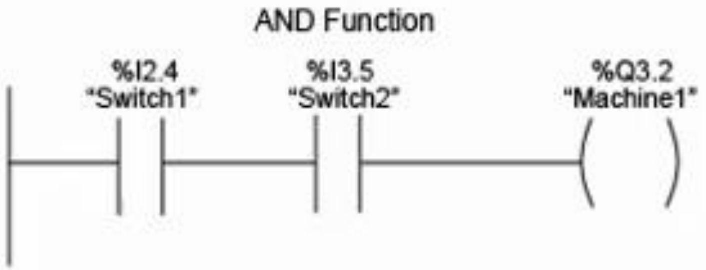
The accompanying graphic shows four LAD instructions. Do not confuse these instructions with electrical devices. These are instructions that follow simple rules.

Because this network includes two series contacts, both contacts must be closed to pass power to the output coil instruction. For this to occur, 12.4 must be 1, and I3.5 must be 0. When this condition exists, Q3.2 is 1. Otherwise, Q3.2 is 0.

Next, consider the truth table for the lower network in the accompanying graphic. The final instruction in this network is an inverted output coil instruction.

The inverted output coil instruction gets its name from the fact that it turns on when the RLO to the instruction is 0, which is an inverted result from that of an output coil instruction. In this example, Q4.1 is on except when I2.4 is 1 and I3.5 is 0.

AND, OR, and Exclusive OR (XOR) instructions



Truth Table

I2.4	I3.5	Q3.2
0	0	0
0	1	0
1	0	0
1	1	1

LAD programs incorporate configurations of instructions that represent logical conditions derived from the Boolean logic used to design computer circuits. Some of the most common Boolean logic functions are the AND, OR, and Exclusive OR (XOR) functions.

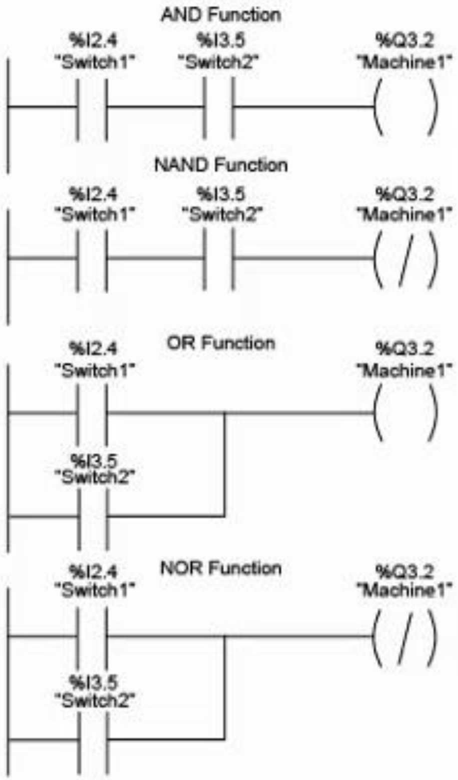
When normally open contact instructions are placed in series leading to an output coil instruction, an AND function is formed.

When normally open contact instructions are placed in parallel leading to an output coil instruction, an OR function is formed.

The XOR function is formed using normally open and normally closed contact instructions leading to an output coil instruction.

Source: Siemens

Inversion



Truth Table

I2.4	I3.5	Q3.2
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table

I2.4	I3.5	Q3.2
0	0	1
0	1	1
1	0	1
1	1	0

Truth Table

I2.4	I3.5	Q3.2
0	0	0
0	1	1
1	0	1
1	1	1

Truth Table

I2.4	I3.5	Q3.2
0	0	1
0	1	0
1	0	0
1	1	0

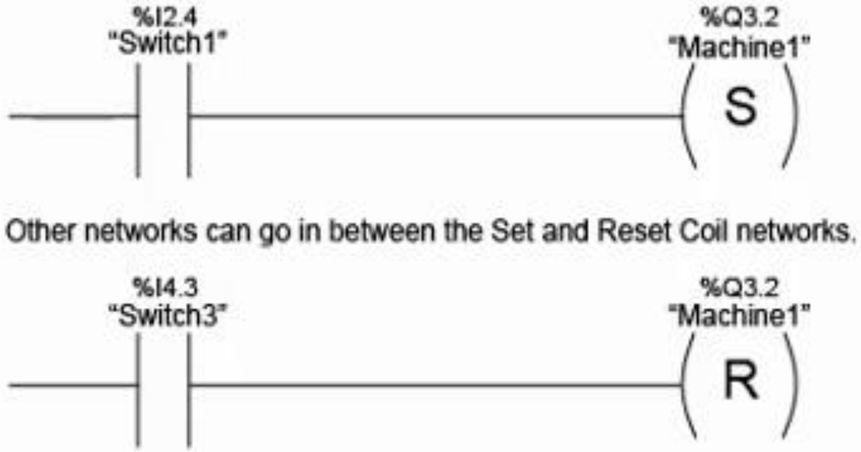
The inverted output coil instruction is one example of inversion, which means changing a 1 to a 0 or a 0 to a 1, and is sometimes called negation.

The AND and OR functions previously described are shown along with similar logic that uses an inverted output coil instruction. Notice that the truth tables for these functions show the resulting states for Q3.2 to be inverted in comparison to the truth tables for the AND and OR functions.

The NOT contact instruction, shown in the accompanying graphic, is another example of a logic inverter. If there is no power flow to the NOT contact instruction, there is power flow after the NOT contact instruction and vice versa. Because the inversion occurs each time the network is scanned, the NOT contact instruction does not have an operand.

Source: Siemens

Instructions that Set and Reset Bits



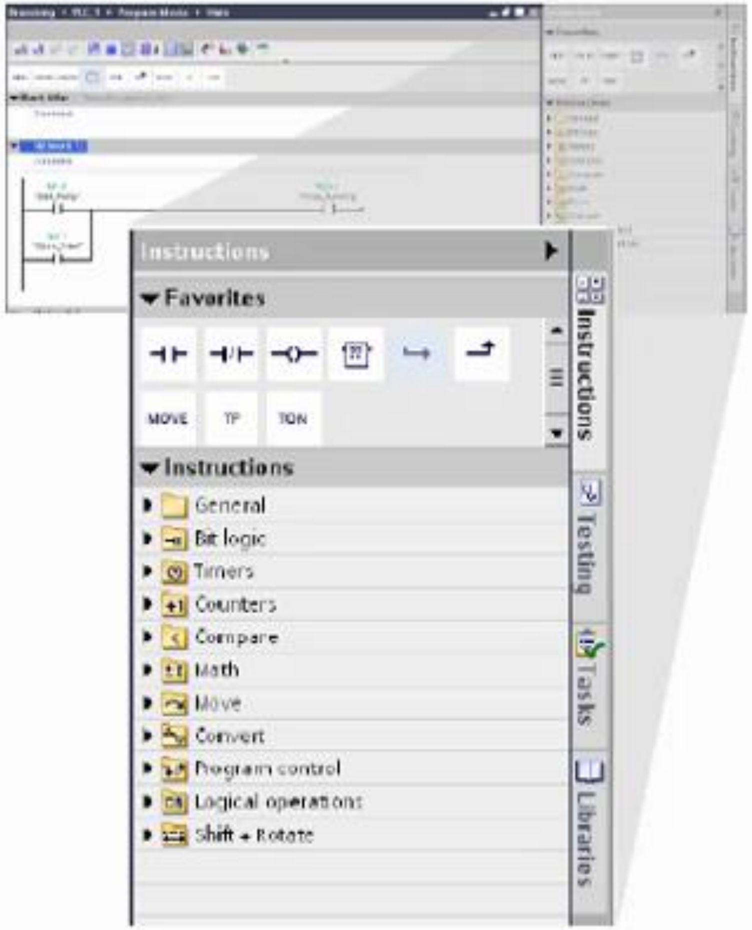
There are a variety of LAD instructions for setting and resetting bits. When there is power flow to the set coil instruction, the bit specified by the instruction's operand is set to 1. When there is power flow to the reset coil instruction, the bit specified by the instruction's operand is reset to 0.

For a set reset flip-flop, when there is power flow to the set (S) input, the output (Q) and the memory bit specified by the operand at the top of the instruction are both set to I.They remain a 1, even if there is no power flow at the set input, until there is power flow at the reset (R) input. For the set reset flip-flop, the reset input is dominant.

The reset set flip-flop instruction functions the same as a set reset flip-flop instruction except that the set input is dominant.

Source: Siemens

Additional Ladder Diagram instructions



The instructions shown in this lesson are only a few of the many types of instructions that can be included in a Siemens PLC LAD program. A LAD program can include a variety of basic and extended instructions.

The basic instructions are grouped in the following categories: bit logic instructions, timers, counters, compare instructions, math instructions, move instructions, convert instructions, program control instructions, word logic instructions, and shift and rotate instructions.

The extended instructions are grouped in the following categories: clock and calendar, string and character, program control, communications, interrupts, PID, motion control, and pulse.

Source: Siemens

Function Block Diagram

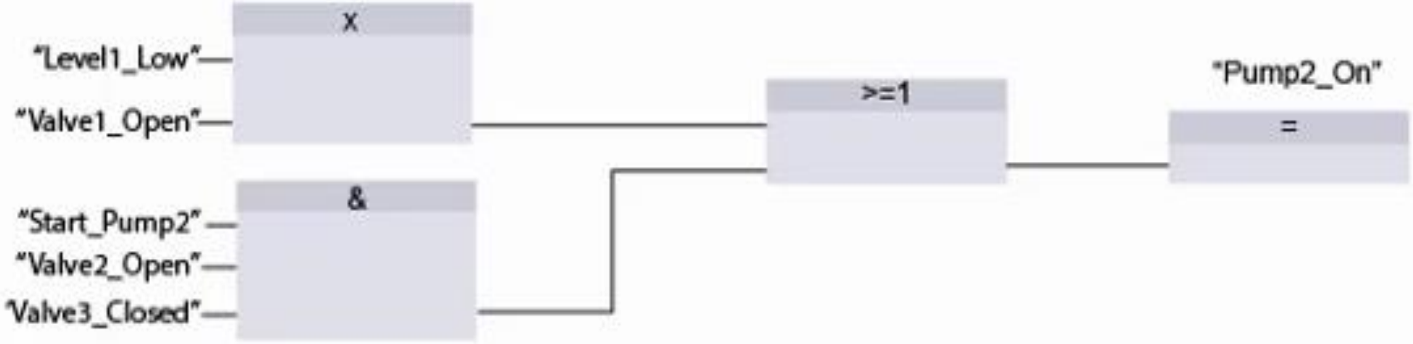
Function Block Diagram Programming

Function block diagram programming (FBD) is a graphical programming language similar to LAD programming and, like a LAD program, an FBD program or program block is composed of numbered networks.

Source: Siemens

Function Block Diagram

Network Execution



As the PLC scans the user program from top to bottom in a program block, each network is scanned from left to right. Just as with a LAD program, the solution for a configuration of instructions is called the result of logic operation (RLO).

The assign instruction is the FBD equivalent to the LAD output coil instruction, both of which store the logical result of the network in the memory location specified by the operand.

When the RLO to the assign instruction is 1, the instruction sets the operand to 1. When the RLO to the assign instruction is 0, the instruction resets the operand to 0.

Source: Siemens

Function Block Diagram

Bit Logic Instructions

As shown in the accompanying graphic, an FBD network is made up of instructions that use the same types of operands and tags as a LAD network.

As with a LAD program, in STEP 7 (TIA Portal) an absolute operand is preceded by %, a global PLC tag is enclosed in quotation marks, and a local tag, which is a tag defined in a program block for use only by that program block, is preceded by#.

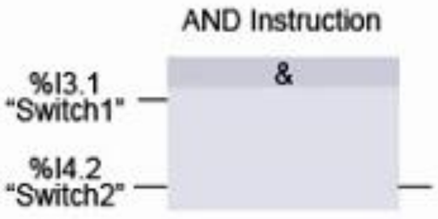
Because the FBD programing language includes many instructions, STEP 7 groups instructions into a number of basic and extended instruction categories. These instructions provide FBD programs with similar capabilities to those of LAD programs.

This lesson provides examples of instructions in the bit logic category.

Source: Siemens

Function Block Diagram

AND Instruction



Truth Table

I3.1	I4.2	Result
0	0	0
0	1	0
1	0	0
1	1	1

Some FBD bit logic instructions are derived from Boolean logic. One of most common of these instructions is the AND instruction.

The operand associated with each instruction input identifies the memory location where a 1 or 0 is stored. The result of the AND instruction is 1 when both the inputs to the instruction are 1's. When there are more than two inputs to the AND instruction, all inputs must be 1's for the result to be 1.

The AND instruction can be combined with other instructions to form a network.

In the accompanying graphic, the AND instruction is combined with an assign instruction that controls the output Q5.2 status bit in the process image table.

In this example, output Q5.2 is 1 when 13.1 and I4.2, are both 1's.

Source: Siemens

Function Block Diagram

OR Instruction

Truth Table

I3.1	I4.2	Result
0	0	0
0	1	1
1	0	1
1	1	1

The OR instruction is another FBD bit logic instruction. The accompanying graphic shows an OR instruction with two inputs, but an OR instruction can have three or more inputs.

The result of the OR instruction is 1 when one or more of the inputs to the instruction are 1's.

The OR instruction can be combined with other instructions to form a network.

In the accompanying graphic, the OR instruction is combined with an assign instruction that controls the output Q5.2 status bit in the process image table.

In this example, output Q5.2 is 1 when one or both of the inputs are 1's.

Source: Siemens

Function Block Diagram

Exclusive OR (XOR) instruction

The result of an FBD Exclusive OR (XOR) instruction is 1 when one of the inputs to the instruction is a 1, but not when both are ones. This rule must be expanded to take into consideration XOR instructions with more than two inputs. The broader rule is that when an odd number of instruction inputs are 1's, the result is a 1, but when an even number of inputs are 1's or when all inputs are 0, the result is 0.

FBD instructions are often combined to form networks that perform more complex functions. For example, the accompanying graphic shows a network of five bit logic instructions.

By analyzing the truth tables shown, you can determine the status of output Q6.2 for any combination of operand statuses.

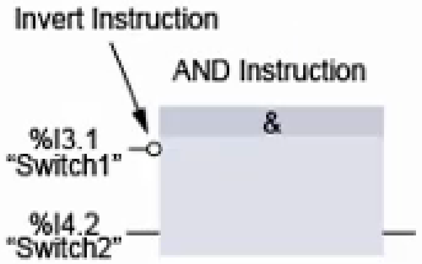
XOR Instruction

Truth Table

I3.1	I4.2	Result
0	0	0
0	1	1
1	0	1
1	1	0

Function Block Diagram

Inversion



Truth Table

I3.1	I4.2	Result
0	0	0
0	1	1
1	0	0
1	1	0

Inversion, also called negation, means to change a 1 to a 0 or vice versa. When applied to FBD programming, an invert instruction is represented by a small circle adjacent to another FBD instruction.

Another type of inversion available for S7-1200 and S7-1500 PLCs is the negate assign instruction. The negate assign instruction inverts the RLO of a network.

Therefore, if the RLO of the network is a 1 without the negate assign instruction, the RLO is a 0 with the instruction, and vice versa.

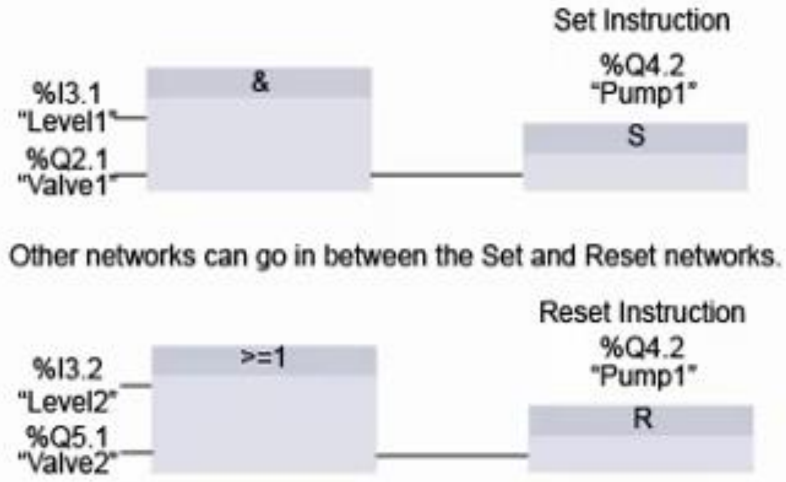
The accompanying graphic shows a network with an OR instruction connected to a negate assign instruction.

As the associated truth table shows, the result of this network is 1 only when both inputs to the instruction are 0's.

Source: Siemens

Function Block Diagram

Instructions that Set and Reset Bits



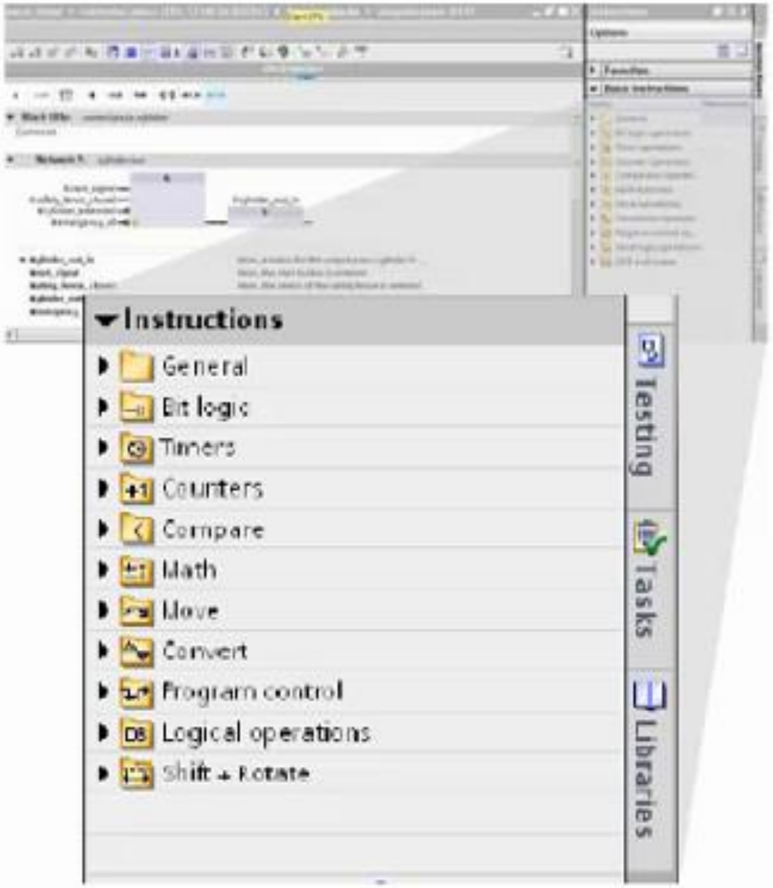
There are a variety of FBD instructions that set and/or reset bits. When the RLO to the left of the set instruction is 1, the instruction sets the specified bit to 1. When the RLO to the left of the reset instruction is 1, the instruction resets the specified bit to 0.

The top network in the accompanying graphic includes a set reset flip-flop, and the bottom network includes a reset set flip-flop. Both networks perform a similar function. When there is a 1 at the set (S) input, the output (Q) and the memory bit specified by the operand at the top of the instruction are both set to l.They remain a 1, even after the set input goes to 0, until there is a 1 at the reset (R) input.

There is one important difference between these instructions. For the set reset flip-flop, the reset input is dominant. For the reset set flip-flop, the set input is dominant. If there is a 1 at both the set and reset inputs, the dominant input controls the result.

Source: Siemens

Additional FBD instructions



The instructions shown in this lesson are only a few of the many types of instructions that can be included in a Siemens PLC FBD program. An FBD program in a Siemens PLC can include a variety of basic and extended instructions.

As you have seen, some of the FBD instructions are different from corresponding LAD instructions, but the instruction categories and overall capabilities of FBD and LAD are very similar.

Source: Siemens